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Effect of sucrose availability on wheel-running as an operant and as a reinforcing consequence on a multiple schedule: Additive effects of extrinsic and automatic reinforcement

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ABSTRACT

As a follow up to Belke and Pierce's (2014) study, we assessed the effects of repeated presentation and removal of sucrose solution on the behavior of rats responding on a two-component multiple schedule. Rats completed 15 wheel turns (FR 15) for either 15% or 0% sucrose solution in the manipulated component and lever pressed 10 times on average (VR 10) for an opportunity to complete 15 wheel turns (FR 15) in the other component. In contrast to our earlier study, the components advanced based on time (every 8 min) rather than completed responses. Results showed that in the manipulated component wheel-running rates were higher and the latency to initiate running longer when sucrose was present (15%) compared to absent (0% or water); the number of obtained outcomes (sucrose/water), however, did not differ with the presentation and withdrawal of sucrose. For the wheel-running as reinforcement component, rates of wheel turns, overall lever-pressing rates, and obtained wheel-running reinforcements were higher, and postreinforcement pauses shorter, when sucrose was present (15%) than absent (0%) in manipulated component. Overall, our findings suggest that wheel-running rate regardless of its function (operant or reinforcement) is maintained by automatically generated consequences (automatic reinforcement) and is increased as an operant by adding experimentally arranged sucrose reinforcement (extrinsic reinforcement). This additive effect on operant wheel-running generalizes through induction or arousal to the wheel-running as reinforcement component, increasing the rate of responding for opportunities to run and the rate of wheel-running per opportunity.

1. Introduction

Running in a wheel is a behavior that can function as both a reinforcing consequence for an operant behavior, such as lever pressing and as an operant behavior producing contingent reinforcement. While the reinforcement function of wheel-running has been studied extensively (e.g., Belke, 1997; Collier and Hirsch, 1971; Iversen, 1993; Kagan and Berkun, 1954), there have been few investigations of wheel-running as an operant (Belke and Pierce, 2014; Iso, 1996; Premack, 1969; Skinner and Morse, 1958). The operant function is of particular interest in the present study, as operant wheel-running results in extrinsic reinforcement for behavior that is itself intrinsically reinforcing. One implication of this intrinsic reinforcement property of wheel-running is that the operant level of wheel-running behavior would be higher than the operant level of lever pressing and this higher level may limit or, perhaps, mask the response-strengthening effect of extrinsic reinforcement on wheel-running. Another possibility is that providing extrinsic reinforcement for wheel-running may undermine intrinsic motivation for this behavior (Deci, 1971; Deci et al., 1999). Extensive research with humans suggests that providing extrinsic reward for an intrinsically motivated behavior can decrease the intrinsic interest or value of that behavior—involving a decrease in the target response below a no reward or baseline condition once extrinsic reward is removed.

Recently, Belke and Pierce (2014) examined the motivational effects of removing sucrose reinforcement, or allowing a period of pre-running, on the reinforcement value of wheel-running, and on operant wheel-running for sucrose, in different components of a multiple schedule. That is, in one component, wheel-running functioned as reinforcement for lever pressing. In the other component, wheel-running functioned as an operant for sucrose reinforcement.

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Stimulus conditions for the two components alternated to signal the different functions of wheel-running. Results showed that prior to either manipulation (sucrose removal or pre-running), sucrose failed to reinforce wheel-running rates, in that wheel-running rates did not differ between the two components. Removal of the sucrose, however, did affect wheel-running. Thus, wheel-running rates in both components decrease with sucrose removal, showing a decline in the intrinsic value of wheel-running; furthermore, the wheel-running rate in the operant component decreased more than the rate in the reinforcement component, indicating a reinforcement effect of sucrose on wheel-running. Access to the running wheel for 1 h prior to a session (pre-running) also decreased wheel-running in both components, but more in the reinforcement component than the operant one. Pre-running reduced the intrinsic value of running in both components; however, in this case, the decline in the operant component was less than in the reinforcement one, also indicating a reinforcement effect of sucrose on wheel-running.

To understand these motivational effects, Belke and Pierce (2014) pointed to three alternative accounts: behavioral contrast, arousal, and intrinsic motivation. The researchers noted that the experimental procedures involve a multiple schedule with removal of sucrose reinforcement in the operant component, suggesting the possibility of behavioral contrast. Specifically, withdrawal of reinforcement in the operant component was predicted to increase the rate of running in the reinforcement component; however, contrary to the prediction, wheel-running decreased in the unchanged reinforcement component. An arousal hypothesis, however, suggested that the contingency between operant wheel-running and sucrose reinforcement would generate a state of arousal, observed as a heightened level of motor activity. Once sucrose reinforcement is withdrawn, the heightened level of arousal would dissipate and the level of wheel-running would decrease in both components, but with a greater decline in the operant component, a prediction supported by the findings. As for intrinsic motivation, the extrinsic reinforcement of wheel-running by sucrose would be expected to undermine the intrinsic motivation of the activity, as indicated by decreases in wheel-running rates in both components. A greater reduction in the wheel-running rates in the operant component should occur based on the removal of the extrinsic reinforcement as well as the reduction in the intrinsic motivation to run. Wheel-running in the unchanged reinforcement component would only be affected by the reduction in the intrinsic motivation to run, showing less of a decrease in rate. The results supported the qualitative predictions of the intrinsic motivation hypothesis.

A fourth account, not originally considered by Belke and Pierce (2014) is automatic reinforcement. In this paper, we conceptualize automatic reinforcement as reinforcement emanating from engaging in the operant behavior itself, not from the programmed experimental contingencies (Skinner, 1953, 1957; Vaughn and Michael, 1982). That is, rats run in their wheels based on the automatic reinforcement that follows—plausibly emanating from the sensory feedback of the activity (sight, sound, and kinesthetic feedback of the wheel, Weasner et al., 1960), from the upward angular momentum and speed of self-generated wheel activity (Sherwin, 1998), something akin to the fun and thrill of going on a roller coaster as a child, or from physiological changes in neural centers of the brain associated with reinforcement (Monroe et al., 2014). With respect to predictions based on automatic reinforcement, wheel-running in the operant component should decrease when extrinsic reinforcement is withdrawn (extinction) and only automatic reinforcement remains available for this behavior. However, the operant level of wheel-running after extinction would remain high, indicating that this behavior is maintained by a source of reinforcement not programmed by the experimental contingencies. Also, following reinstatement of extrinsic reinforcement, recovery of the operant level of wheel-running during a second extinction phase should not differ from the operant level of initial extinction, as the contingencies of automatic reinforcement are still in effect. Finally, when there is no extrinsic reinforcement for operant wheel-running, wheel-running rates in the reinforcement component should approximate those in the operant component, as wheel-running in both components would be maintained solely by automatic reinforcement.

Given that the concepts of automatic reinforcement and intrinsic motivation or intrinsic reinforcement appear interchangeable, it is important to note that the concept of automatic reinforcement, unlike intrinsic motivation, does not predict an undermining effect due to the extrinsic reinforcement. The concept of intrinsic motivation is inextricably linked to the undermining effect. Automatic reinforcement, on the other hand, makes no prediction about how it interacts with an extrinsic source of reinforcement. In addition, a behavior maintained by automatic reinforcement can be affected by operations similar to those that affect a behavior maintained by extrinsic reinforcement.

Another important consideration is that the multiple schedule in Belke and Pierce's (2014) study used linked components, which could have limited the generality of the findings. Rats on a VR 10 schedule of lever pressing for wheel-running reinforcement (reinforcement component) were required to complete 15 wheel revolutions during each reinforcement interval and repeat the entire sequence 10 times (150 wheel turns and 10 reinforcers) to advance to the operant component. In the operant component, rats had to complete 15 wheel revolutions for each sucrose presentation and repeat the sequence 10 times (150 wheel turns and 10 reinforcers) to advance to the reinforcement component. This linked procedure insured that the number of revolutions and reinforcers in each component were equivalent. One implication of the linked procedure is that rats could not generate differences in obtained reinforcers between the operant and the reinforcement components, which would have indicated the relative value of the reinforcers in the two components. That is, the rats were unable to increase wheel-running to produce more sucrose reinforcers in the operant component than wheel-running reinforcers in the reinforcement component. To address this problem and provide more evidence on the motivational or automatic reinforcing nature of wheel-running, the current study used an unlinked multiple-schedule procedure. In an unlinked procedure, components advance when the component duration elapses. Advancement of the schedule is independent of the behavior occurring on the reinforcement schedule within a component, allowing for an assessment of the relative values of wheel-running and sucrose.

Finally, for the sake of greater clarity, in the current study, the component in which wheel-running was arranged to function as an operant and in which the presence and absence of sucrose was manipulated will be referred to as the "focal" component. The component in which wheel-running was arranged to function as a reinforcer for lever pressing and in which there was no direct manipulation will be referred to as the "unchanged" component.

2. Method

2.1. Participants

Nine female Long–Evans rats obtained from Charles River Breeding Laboratories in St. Constant, Quebec served as subjects. The rats were approximately 10 months old at the onset of the experiment. Prior to beginning this study, the rats had been trained to press a lever in a standard operant conditioning chamber as part of an exercise in a course on Conditioning. In their colony