Short report

Contrafreeloading, reinforcement rate, and behavioral momentum

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ABSTRACT

Contrafreeloading involves organisms working for food when an identical source of food is freely available. The present study assessed whether training reinforcement rates influenced contrafreeloading by arranging a within-subject and within-session design using pigeons. Across different alternating discriminative stimuli, variable-interval schedules arranged leaner (30 per hour) and richer (120 per hour) rates of food reinforcement. Responding decreased but persisted in the presence of free food during the session (i.e., contrafreeloading). Further, responding tended to be similar between components initially but greater persistence emerged in the richer component with additional exposure. With pre-session feeding, responding did not change systematically across test sessions and tended to be more persistent in the richer component. Greater persistence with greater training reinforcement rates is generally consistent with an influential theory of response persistence, behavioral momentum theory. However, the different patterns of responding across test sessions between pre- and within-session feeding reveals multiple behavioral processes involved in contrafreeloading that have yet to be fully understood. Behavioral momentum theory could provide a useful theoretical framework for understanding and quantifying the behavioral processes underlying contrafreeloading.

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1. Introduction

Contrafreeloading is the engagement in work to obtain a resource (e.g., food) when the same resource is freely available (Osborne, 1977; Ogura, 2011). For example, Lentz and Cohen (1980) found that pigeons continued to peck keys to obtain food despite the free availability of food in a nearby dish. Contrafreeloading is counterintuitive, as well as inconsistent with "rational" theories of behavior. Optimal foraging theory (e.g., Stephens and Krebs, 1986) and refinements of the matching law (e.g., melioration, maximization; see Williams, 1988) predict exclusive preference for free food. Why do animals engage in contrafreeloading when an immediate and virtually effort-free alternative is available? Although a number of variables influence contrafreeloading (de Jonge et al., 2008; Inglis et al., 1997, 2001; Osborne, 1977; Podlesnik and Shahan, 2009), the behavioral processes underlying contrafreeloading continue to be open to debate.

The degree of contrafreeloading is modified by a number of experimental variables (see Inglis et al., 1997; Osborne, 1977;

Salamone et al., in press, for reviews). In the context of operant conditioning, contrafreeloading can occur without prior operant training (e.g., Neuringer, 1969; Rutter and Nevin, 1990). However, greater training of the operant response (e.g., Jensen, 1963; Lentz and Cohen, 1980; Mitchell and White, 1977) and lower response requirements (e.g., Carder and Berkowitz, 1970; Milella et al., 2008) increase contrafreeloading. One way to conceptualize the effects of these training variables is the freely available food disrupts operant responding. That is, more extensive training or richer reinforcement schedules produce more persistent responding (i.e., contrafreeloading) in the presence of disruption by the freely available commodity. Conceptualized in this way, increased contrafreeloading with more reinforcement in training is generally consistent with one theory of response persistence—behavioral momentum theory.

According to behavioral momentum theory, stronger Pavlovian associations between discriminative stimuli and reinforcement produce responding that is more persistent when challenged under conditions of disruption (see Nevin, 1992a,b; Nevin and Grace, 2000; for reviews; but see Bell, 1999; Grace et al., 1998; Podlesnik and Shahan, 2008, for counterexamples). For example, responding in multiple-schedule components maintained by greater rates and larger magnitudes of reinforcement produce responding that is more resistant to presession satiation, extinction, and
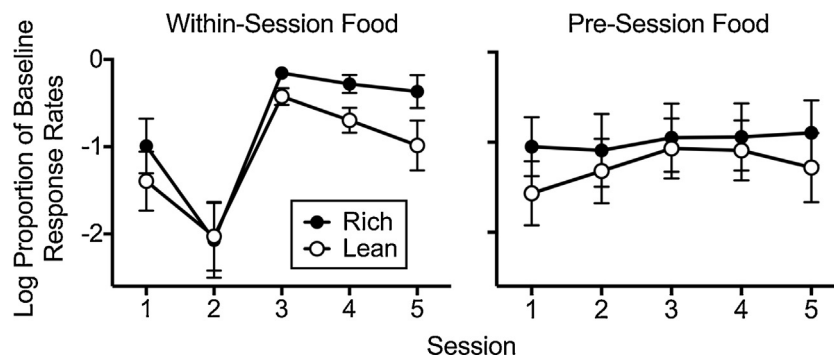
Fig. 1. Resistance to disruption across sessions as log proportion of baseline response rates in the Rich and Lean components as a function of successive sessions of within-session feeding (left) and pre-session feeding (right). Error bars represent standard errors.

alternative sources of reinforcement (e.g., Nevin et al., 1990; Podlesnik and Shahan, 2010). If a free source of food during a session disrupts operant responding much like these more traditional sources of disruption (e.g., pre-session feeding), contrafreeloading also should be greater in the presence of stimuli arranging higher reinforcement rates. Moreover, differences in patterns from pre-session feeding could provide insight into processes involved in contrafreeloading. Therefore, the present study compared resistance to disruption by arranging a freely available food source either before or during experimental sessions with different training reinforcement rates in pigeons. In addition, we arranged multiple sessions of pre- and within-session feeding because previous studies revealed changes in pattern of responding with duration of exposure to free food and contrafreeloading (e.g., Amato et al., 2006; Nau et al., 1981).

2. Method

2.1. Subjects

Eight unsexed homing pigeons with experience responding in multiple schedules were maintained at approximately 80% of their free-feeding weights by postsession supplemental feeding of pelleted pigeon chow as necessary. Pigeons had free access to water when housed in individual cages in a temperature-controlled room with a 12:12 h light/dark cycle (lights on at 7:00 a.m.).

2.2. Apparatus

Four ventilated sound-attenuating chambers were constructed of clear plastic and aluminum with two response keys centered directly above a solenoid-operated hopper filled with pigeon chow. During 2-s hopper presentations, the opening was lit with a white light, and the houselight and keylight were turned off. A plastic food bowl (15 cm diameter × 6 cm tall) was placed in the back of the chamber on the right side during all sessions. Med Associates® interfacing and software controlled experimental sessions.

2.3. Procedure

A two-component multiple schedule arranged food reinforcement according to a variable-interval (VI) 30-s schedule (hereafter Rich component) and a VI 120-s schedule (hereafter Lean component). All lights were turned off during 30-s intercomponent intervals (ICI), which preceded all 60-s components. All VI schedules were comprised of eight intervals (Fleshler and Hoffman, 1962) selected without replacement. Both left and right keys were used, with red and green keylights signaling components that were counterbalanced across pigeons. Sessions began immediately after

placing the pigeons in the chamber. The first component was randomly chosen followed by strict alternation. Each component was presented 10 times.

Responding was judged visually to be stable in all pigeons following 17 baseline sessions. Next, 150 g of pigeon chow was placed in the food bowl during 5 consecutive sessions (i.e., within-session feeding). Once 80% free-feeding weight was reestablished, six additional baseline sessions followed during which responding was visually stable. Finally, 30 min before five consecutive sessions, 150 g of pigeon chow was placed in a food bowl in the pigeons' home cages. Pigeons never finished all the food with either disrupter—unfortunately, exact records of food remaining in bowls and pigeon weights were lost.

3. Results

Alpha was set to 0.05 for all statistical tests. All baseline measures were calculated across six sessions prior to disruption. Obtained reinforcers per hr in baseline were slightly lower but approximated arranged rates in the Rich (M = 115.6, SEM = 4.7) and Lean (M = 26.3, SEM = 3.9) components. Responses per min were greater in the Rich component (M = 93.0, SEM = 25.9) compared to in the Lean component (M = 61.2, SEM = 14.9). Greater response rates in the Rich component were supported by a two-way (component x condition) repeated-measures ANOVA with a significant effect of component, $F(1, 7) = 15.40$, $p = 0.006$, $\eta^2 = 0.688$, and no significant effect of condition or interaction.

Below we assessed logarithmic proportions of baseline response rates because this measure often is used in studies of resistance to disruption to normalize differences in baseline response rates (Nevin and Grace, 2000). If response rates were zero for a measure in one component, one response was added to that component. If response rates were zero for a measure in both components, we added one response to both components. Next, the greater value was assigned for both components to retain equal values, as not to make responding artificially more persistent in one component. Fig. 1 shows the log ratio of response rates during disruption sessions to mean baseline response rates in the Rich and Lean components for within-session (left) and pre-session (right) feeding. Overall, responding was greater in the Rich component for both disruption tests. However, within-session feeding produced a different pattern of disruption across sessions than pre-session feeding. With within-session feeding, responding tended to increase during the third session and the Rich and Lean functions separated in Sessions 4 and 5. With pre-session feeding, there were no systematic changes across sessions. These findings were supported with two-way (component x session) repeated-measures ANOVAs. For within-session feeding, there was a significant component x session interaction, $F(4, 28) = 5.86$, $p = 0.001$, $\eta^2 = 0.456$.