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Discriminative control of variability: Effects of successive stimulus reversals

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Abstract

A growing body of evidence suggests that behavioral variability can come under control of discriminative stimuli. The present experiment further examined discriminative control of variability in a novel way by using the discrimination-reversal paradigm. Eight pigeons responded under a multiple schedule of Vary and Yoke components signaled by different-colored keylights. In the Vary component, 4-response sequences that differed from the previous 10 produced food, while in the Yoke component, any 4-response sequence had a fixed probability of producing food, yoked to the prior Vary component. Following stability in this procedure, the key colors signaling the Vary and Yoke components were reversed across four successive conditions. Across the experiment, variability of keypeck sequences was higher in the Vary than in the Yoke component. Across successive reversals, the level of variability in the Vary component adapted more rapidly to the reversed contingencies, while the rate of adaptation in the Yoke component did not change systematically. These results are interpreted in terms of the different contingencies in the Vary and Yoke components. In addition, the improvement in the rate of adaptation across successive reversals in the Vary component appears consistent with a proactive interference account of discrimination-reversal performance. These results join others in suggesting that variability may be an operant dimension of behavior.

Keywords: Behavioral variability; Discriminative control; Discrimination reversal; Proactive interference; Adaptation; Keypeck; Pigeon

Behavioral variability is adaptive. For example, a predator may change the technique and scope of its hunt to adjust to changing migratory patterns of prey, and animals may modify their foraging patterns to adapt to changes in their environments (e.g., Agetsuma and Noma, 1995; Goulson et al., 1997; Lewis et al., 2004). The faster the adaptation, the more likely the organism is to survive. The fact that many organisms survive such changes in their ecological environments over the course of their lifetime suggests that they *learn* to adapt, which may require behaving in a variable fashion when previously successful response strategies prove ineffective. Accordingly, conceptual and methodological frameworks employed to study learning phenomena (and more specifically, operant behavior) have been applied to the study of behavioral variability.

Operant behavior has two defining characteristics (Skinner, 1953). First, the behavior must be controlled by its consequences. An operant behavior that is followed by a reinforcer increases in probability. Second, discriminative control of the behavior must be demonstrated. The behavior should occur under particular stimulus conditions, and should not occur under others, in accord with the contingencies in place. If some aspect of behavior satisfies these two criteria, it can be said to be operant. Much research has focused on the operant nature of behavioral variability (see Neuringer, 2002, 2004 for reviews).

In terms of the first criterion for operant behavior, control of variability by reinforcement contingencies has been demonstrated in a variety of species, including rats, pigeons, dolphins, and humans (e.g., Blough, 1966; Bryant and Church, 1974; Neuringer, 1986; Page and Neuringer, 1985; Pryor et al., 1969). For example, Page and Neuringer assessed variability of 8-response keypeck sequences in pigeons across two conditions: Vary and Yoke. In one condition of Experiment 5, response sequences during the Vary condition produced food if the present sequence differed from the previous 50 sequences (lag 50). In the Yoke condition, response sequences produced food if on

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that trial during the Vary condition a reinforcer had been earned. Thus, reinforcers were dependent on variability in the Vary condition, but not in the Yoke condition. Page and Neuringer found that variability of response sequences was significantly higher in the Vary condition than in the Yoke condition, suggesting that variability was under control of the reinforcement contingencies. In addition, variability can be produced with a variety of different response topographies (e.g., Blough, 1966; Goetz and Baer, 1973; Morgan and Neuringer, 1990; Pryor et al., 1969). Furthermore, the level of behavioral variability depends on the reinforcement contingencies; when a high level of variability is required for reinforcer delivery, a high level is emitted, and vice versa (e.g., Wagner and Neuringer, 2006). Thus, a large body of evidence suggests that behavioral variability can be controlled by its consequences.

The results of a number of studies also suggest that variable behavior can come under discriminative control (e.g., Cohen et al., 1990; Odum et al., 2006; Ward et al., 2006; Page and Neuringer, 1985). Denney and Neuringer (1998) provided compelling evidence for such control. In two experiments with rats, they examined discriminative control of variability in a multiple schedule of Vary and Yoke components. In the Vary component, signaled by constant illumination of the houselight, infrequently emitted 4-response sequences produced food. In the Yoke component, signaled by the presence of a continuous tone, each 4-response sequence had a fixed probability of producing food (yoked to the overall frequency of reinforcers in the Vary component). Under this procedure, the measure of variability was higher in the Vary component than in the Yoke component. In Experiment 2, when the discriminative stimuli in both components were removed, variability converged at an intermediate level. When the discriminative stimuli were returned, the level of variability in the Vary and Yoke components once again diverged. These results indicate that variability can come under the control of discriminative stimuli.

Discriminative control of learned behavior has been widely studied using the discrimination reversal preparation (see Mackintosh et al., 1985). In a typical discrimination reversal experiment, responses to one of two stimuli are reinforced. Following attainment of a learning criterion or completion of an arbitrary number of trials, the discrimination is reversed, and responses to the other stimulus are reinforced. For example, Staddon and Frank (1974) assessed performance across successive discrimination reversals. In Experiment 1, pigeons responded under a multiple schedule of S+ and S− components, signaled by different combinations of a white form superimposed on a colored background of a lit response key. During S+ components, pecks to the response key produced food according to a variable interval 60-s schedule. During S− components, responses did not produce food. Across successive conditions, the stimuli signaling S+ and S− were reversed. On the first day of reversal 1, the percentage of responding to S+ was less than 30% for all pigeons. By contrast, on the first day of reversal 30, performance had greatly improved, with around 90% of responses occurring to S+. In addition to these results, progressive improvement in discrimination performance over the course of successive reversals has been demonstrated in monkeys (e.g., Clarke et al., 2004; Roberts et al., 1990; Schusterman, 1962), rats (e.g., Bitterman, 1969; Watson et al., 2005), and humans (e.g., Teng, 1998).

Although previous results suggest that variable behavior can come under control of discriminative stimuli, no studies have examined discriminative control of variability within the discrimination reversal paradigm. Demonstration of discriminative control across successive reversals may provide further evidence for the operant nature of variability. In the present experiment, pigeons responded under a multiple schedule of Vary and Yoke components, each signaled by different colored keylights. In the Vary component, 4-response sequences that differed from the previous 10 produced food (lag 10). In the Yoke component, the probability of food for each 4-response sequence was yoked to the average probability of food from the Vary component. Following stability on this procedure, the stimuli signaling the Vary and Yoke components were reversed across four successive conditions. Two specific questions guided the present experiment. First, we were interested to see whether discriminative control of variability would be achieved across reversals. Second, we were interested to see whether the level of variability in each component would adapt more quickly to the reversed contingencies across successive reversals.

1. Method

1.1. Subjects

Eight homing pigeons that had prior experimental histories with a variety of related procedures served as subjects. Pigeons were maintained at 80% ± 15 g of their free-feeding weight by postsession feeding as needed. Between sessions, pigeons were individually housed in a temperature-controlled colony under a 12-light:12-h dark cycle and had free access to water. This research was approved by the Utah State University Institutional Animal Care and Use Committee.

1.2. Apparatus

Four standard 29 cm × 26 cm × 29 cm clear plastic and aluminum operant chambers were used. Each chamber was equipped with two 2.5 cm response keys that required a force of about 0.1 N to operate. The keys could be illuminated from behind with red or green light. A 28 vDC shielded houselight provided chamber illumination. A 6 cm × 5 cm aperture centered directly below the response keys and 5 cm from the chamber floor allowed access to pigeon chow from a raised solenoid-operated hopper. During hopper presentations, the houselight and keylights were extinguished and the hopper aperture was lit by a 28 vDC bulb. Contingencies were programmed and data collected using Med Associates® interfacing and software.

1.3. Procedure

Experimental sessions were conducted 5 days a week at approximately the same time each day. Due to the subjects'