



# Response elimination, reinforcement rate and resurgence of operant behavior



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## ABSTRACT

The effects of reinforcement rate of alternative responding on resurgence were studied in six experiments with pigeons. In Experiment 1A, key pecking was maintained on a multiple variable-interval (VI) VI schedule in the Training phase. In the Response-Elimination phase, a variable differential-reinforcement-of-other-behavior (DRO) schedule was in effect in each component. Reinforcement rates were equal and then, higher in one (rich) component, and lower in the other (lean), than in the Training phase. More resurgence occurred in the lean component, but this could have resulted from response-rate differences between components in the Training-phase. Experiment 1B was a replication of Experiment 1A, but with experimentally-naïve pigeons. Response-Elimination phase reinforcement rates were manipulated systematically in subsequent experiments: In Experiment 2, reinforcement rate was equal, in one component, and lower or higher in the other, than in the Training phase. In Experiment 3, reinforcers were discontinued before differential reinforcement rates were effected. In Experiment 4, reinforcement rates first were differential and, then, equal to those in the Training phase. In Experiments 5 and 6, differential reinforcement rates were arranged by using fixed-DROs and VIs for pecking a different key, respectively. Even though resurgence was not obtained with every pigeon, at least some small-magnitude resurgence occurred in each experiment and was not related systematically to reinforcement rates of alternative responding. Schedule differences, response topography, order of conditions and the length of each phase were not sufficient to account for these results.

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## 1. Introduction

Resurgence, the occurrence of previously reinforced responding when reinforcers for current responding are discontinued (Epstein, 1983, 1985), is studied commonly by using three-phase procedures (Carey, 1951; Leitenberg et al., 1970; Leitenberg et al., 1975; Lieving and Lattal, 2003). In the first, *Training*, phase, a response is reinforced. In the second, *Response-Elimination*, phase, reinforcers for the first response are discontinued and an alternative response is reinforced. In the third, *Resurgence*, phase, reinforcers for the alternative response *also* are discontinued. Resurgence is operationalized in this phase as an increase in the occurrence of the first response relative to the terminal sessions of the Response-Elimination phase (da Silva et al., 2008; Doughty et al., 2007; for

reviews see Doughty and Oken, 2008; Lattal and St. Peter Pipkin, 2009).

Previous studies indicate that resurgence is affected by response and reinforcement rates in the Training phase, and by the schedules, the topography and the reinforcement rate of alternative responding in the Response-Elimination phase. More resurgence has been reported when Training-phase response (da Silva et al., 2008; Winterbauer et al., 2013; see also Bouton et al., 2012) and reinforcement rates are high rather than low (Podlesnik and Shahan, 2009, 2010). The effects of Response-Elimination phase variables on resurgence, however, have been inconsistent across studies. For example, lengthier Response-Elimination phases have been suggested to reduce the occurrence of resurgence. Leitenberg et al. (1975; Experiment 4), for example, found that resurgence of rats' lever pressing was inversely related to the length of the Response-Elimination phase (3, 9 or 27 days). Cleland et al. (2000), in a study with hens, also reported more resurgence of a door push or a head bob response (for different hens) when alternative responding was reinforced immediately after the Training phase than after nine extinction sessions. By contrast, Lieving and Lattal (2003; Experiment 1) reported no differential resurgence of pigeons' key pecking after Response-Elimination phases of 10, 30-min, extinction sessions followed by either 5 or 30 sessions in which treadle pressing

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was reinforced. Winterbauer et al. (2013) also reported no differential resurgence of rats' lever pressing after Response-Elimination phases of 4, 12 or 36 sessions. Procedural differences between these studies (e.g., species, topography of Training-phase and of alternative responding, the schedules of reinforcement maintaining responses in each of these phases) however, might be responsible for the inconsistent results obtained when the length of the Response-Elimination phase was manipulated.

Inconsistent results also have been reported for the effects on resurgence of different schedules of reinforcement and topography of alternative responding in the Response-Elimination phase. Leitenberg et al. (1975, Experiment 2; see also Winterbauer and Bouton, 2010, Experiment 4) reported no differential resurgence of rats' lever pressing when either a fixed-ratio (FR) or a variable-interval (VI) schedule were in effect in the Response-Elimination phase. Pacitti and Smith (1977), however, found more resurgence of rats' lever pressing when the schedule in the Response-Elimination phase was an FR for either pressing a different lever or for pole pushing than a differential reinforcement of other behavior (DRO). Additionally, Mulick et al. (1976, Experiment 1), using a three-component multiple schedule, reported little to no resurgence of squirrel monkeys' lever pressing (previously maintained by a VI 30 s in each component) when, in the Response-Elimination phase, extinction was in effect in one component, a DRO 20 s or 30 s in the other, and a fixed-interval (FI) 20 s or 30 s for pressing a different lever in the other component.

Doughty et al. (2007) addressed the same questions as Pacitti and Smith (1977) and Mulick et al. (1976), and presented data suggesting that more resurgence occurs when responses in the Training and Response-Elimination phases are topographically different. In their study, pigeons' key pecking first was reinforced on a multiple VI 30 s VI 30 s. In the Response-Elimination phase, across experiments, variable- and fixed-DROs, and VI schedules for either pecking a different key or treadle pressing, were in effect in each component. In general, more resurgence occurred in the components correlated with either DRO schedule than with a VI for pecking a different key. Additionally, resurgence was not differential when a DRO and a VI for treadle pressing were in effect in each component (Experiment 4), suggesting that more resurgence might occur when Training and Response-Elimination phase responding differ in topography.

Conflicting results also have been found concerning the effects of reinforcement rate of alternative responding on resurgence. Leitenberg et al. (1975; Experiment 3), for example, reported more resurgence of pigeons' key pecking when, in the Response-Elimination phase, pecking a different key was maintained by higher (VI 30 s) rather than lower (VI 240 s) reinforcement rates. Based largely on these findings, Leitenberg et al. (see Rawson et al., 1977; see also Cleland et al., 2001) proposed the "prevention-of-extinction", or "response-prevention", hypothesis of resurgence, according to which higher reinforcement rates of alternative responding should prevent Training-phase responding from being extinguished more than lower reinforcement rates, leading to greater resurgence when reinforcement of alternative responding is discontinued. That is, the more Training-phase responding occurs during the Response-Elimination phase, the more complete its extinction and the lower its probability of resurgence. Winterbauer and Bouton (2010, Experiments 1 and 2), by contrast, reported no differential resurgence after exposing rats in different groups to schedules arranging an increase, a decrease, or no change in reinforcement rate of alternative responding relative to the Training phase. Although the effects of the rate of reinforcement of alternative responding on resurgence have not been established consistently, quantitative models have been proposed in which such rates are an important determinant of resurgence (e.g., Cleland et al.,

2001; Shahan and Sweeney, 2011; n.b., the "response-prevention" hypothesis is an important mechanism by which resurgence is explained in Cleland et al.'s, but not in Shahan and Sweeney's model).

Shahan and Sweeney (2011), for example, proposed a model of resurgence based on behavioral momentum theory. They assumed that reinforcement of alternative responding both disrupts the occurrence of Training-phase responding during the Response-Elimination phase and increases its strength and subsequent resurgence. The model predicts more resurgence when higher reinforcement rates of alternative responding are in effect and also that the degree of differential resurgence is a function of the schedule values (i.e., of reinforcement rates) in the Training and Response-Elimination phases. Shahan and Sweeney reported hypothetical data based on simulations of their model in which a multiple VI 30-s VI 120-s schedule was in effect in the Training phase and, in the Response-Elimination phase, equal VIs were in effect in each component, the values of which were varied between 240 s and 15 s. Increasing the rate of reinforcement of alternative responding produced more resurgence in both components. Additionally, resurgence was less differential between components when higher reinforcement rates of alternative responding were in effect (see their Fig. 4, p. 100).

The present experiments were conducted to further study the effects reinforcement rate of alternative responding on resurgence. As the effects of this variable on resurgence were studied previously by using between-subject analyses (e.g., Leitenberg et al., 1975; Winterbauer and Bouton, 2010), and quantitative models of resurgence have been based largely on data from these studies (particularly on the results of Leitenberg et al., 1975, Experiment 3; see Cleland et al., 2001; Shahan and Sweeney, 2011; see also Nevin and Shahan, 2011), the present experiments extended these previous studies by conducting within-subject analyses of resurgence as a function of differential reinforcement rates of alternative responding.

## 2. Experiment 1

In Experiment 1A resurgence was studied when alternative responding was maintained by higher and lower reinforcement rates relative to the Training phase. Experiment 1B was a replication of Experiment 1A with four experimentally naive pigeons.

### 2.1. Experiment 1A

#### 2.1.1. Materials and methods

2.1.1.1. *Subjects.* Three male and one female (627) White Carneau pigeons served. Each was maintained at 80% ( $\pm 15$  g) of its free-feeding weight and housed individually, with free access to water and health grit, in a colony room with a 12 h:12 h light: dark cycle (lights on at 7:00 am).

2.1.1.2. *Apparatus.* Four operant chambers (30-cm long  $\times$  32-cm wide  $\times$  38-cm high) located in sound attenuating enclosures were used. For three chambers, the front wall was an aluminum panel with three 2-cm diameter Gerbrands Co. response keys, 9 cm apart (center to center), with their lower edge 25 cm from the floor. Only the center key was used and it could be operated by a minimum force of 0.15 N and transilluminated red or amber, in one chamber, and red or green, in the other two. The front aluminum panel of the fourth chamber had two response keys. Only the left key was used and could be transilluminated red or amber. Two 28-V white houselights located in the lower right corner of the front panel, for three chambers, and in the upper right corner, for the fourth, provided general illumination. A hopper, located behind a rectangular aperture (5 cm  $\times$  4 cm) at the center of the front panel, with

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