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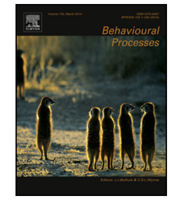

Stimulus generalization and operant context renewal

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ABSTRACT

Context renewal is the relapse of an extinguished response due to changing the stimulus context following extinction. Reinforcing operant responding in Context A and extinguishing in Context B results in relapse when either returning to Context A (ABA renewal) or introducing a novel Context C (ABC renewal). ABA renewal typically is greater than ABC renewal. The present study assessed whether renewal might be conceptualized through excitatory and inhibitory generalization gradients inferred from studies of stimulus generalization. We arranged one keylight-color alternation frequency for pigeons to signal reinforcement in Phase 1 and a different alternation frequency to signal extinction in Phase 2. During a subsequent test in extinction, we presented a range of keylight-alternation frequencies and found renewal to be a function of keylight-alternation frequency. Specifically, Phase-3 responding increased as keylight-alternation frequency differed from that arranged during extinction in Phase 2. Moreover, we observed a shift in the function beyond the originally reinforced keylight-alternation frequency arranged in training (i.e., peak shift). We discuss the relevance of these findings for conceptualizing stimulus-control processes governing generalization gradients for understanding the processes underlying context renewal.

1. Introduction

Relapse is a multidimensional process in which problem behavior recurs once eliminated. Relapse is commonly observed in a range of undesirable behavior, including drug addiction (see Marchant et al., 2013), anxiety (Vervliet et al., 2013), and noncompliant behavior in individuals with developmental disabilities (see Nevin and Wacker, 2013). Laboratory models of relapse phenomena allow for the identification and systematic evaluation of events that might lead to relapse in a variety of clinical settings. One condition shown to produce relapse is context renewal, which is observed when transitioning from the stimulus context in which the target behavior was eliminated (e.g., treatment setting) to either the original learning context or an entirely novel context (see Bouton and Todd, 2014; Bossert et al., 2005; Conklin and Tiffany, 2002; for reviews).

In a laboratory model with rats, Todd et al. (2012) showed that changing features of the contextual stimuli in the operant chamber (e.g., odor, flooring, wall patterns) renewed extinguished operant behavior. In the Phase 1 training context, they reinforced rats' lever pressing in the presence of one set of global contextual stimuli (Context A). In the Phase 2 extinction context, they extinguished lever pressing in a novel context (Context B). Finally, in the Phase 3 renewal-test context, they assessed renewal by returning the rats to either the training Context A or a novel Context C while maintaining the extinction contingency. Both renewal tests of reintroducing Context A (i.e., ABA renewal) and presenting the novel Context C (i.e., ABC renewal) produced reliable renewal of lever pressing (see also Bouton et al., 2011). ABC renewal implies that simply transitioning from the extinction Context B to a different context is sufficient to produce relapse of responding. These findings suggest that treating problem behavior in a different stimulus context (e.g., treatment clinic) from that in which problem behavior was acquired (e.g., home, school) is sufficient to produce relapse when individuals return to any non-treatment settings (see Kelley et al., 2015, for a discussion).

The size of the renewal effect appears to be related to how similar the testing context in Phase 3 is to the training Context A and extinction Context B. For example, returning to the training Context A most frequently produces greater renewal than introducing a novel Context C during Phase 3 (Bouton et al., 2011; Todd et al., 2012 but see Todd, 2013). These findings suggest the similarity between the training context in Phase 1 and testing context in Phase 3 will impact the size of the renewal effect. In addition, Todd et al. revealed that a more distinct Context B in Phase 2 relative to the A or C contexts in Phase 3 produced greater renewal compared to a less distinct Context B. Therefore, the similarity between the extinction

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context in Phase 2 and testing context in Phase 3 appears to impact the size of the renewal effect. Indeed, renewal effects appear to be influenced by how similar the Phase-3 context is to both training and extinction contexts (see McConnell and Miller, 2014; for a discussion of other factors influencing renewal effects).

The similarity of the test context in Phase 3 to both the training and extinction contexts influencing renewal resembles findings typical of the broader literature on stimulus control. In studies of stimulus control (e.g., Guttman and Kalish, 1956), test stimuli more similar to training stimuli paired with reinforcement produce more responding than test stimuli more similar to training stimuli paired with extinction (see Honig and Urcuioli, 1981; Lazareva, 2012; Rilling, 1977; for reviews). The findings above by Todd et al. (2012), revealing greater renewal following a more distinct extinction Context B, suggests renewal might be governed by the same stimulus-control processes as responding in tests of stimulus generalization. Methods designed to assess generalization gradients and renewal arrange generally similar training and testing conditions, as both methods arrange stimuli differentially paired with reinforcement and extinction followed by presenting stimuli in extinction tests. However, differences in procedure exist that pose a barrier to addressing the hypothesis of whether the same processes govern stimulus generalization and renewal.

Studies assessing generalization gradients typically alternate stimuli differentially paired with reinforcement (S+) and extinction (S−) within a training condition (e.g., Fox et al., 2013; Hanson, 1959). Testing in another phase or probe sessions assess how a range stimuli from a single dimension control responding, such as flash rate (e.g., Fox et al., 2013) or color wavelength (e.g., Guttman and Kalish, 1956; Hanson, 1959). Thus, determining what aspects of stimuli differentially control responding during testing is relatively straightforward. If the same stimulus-control processes govern renewal and responding during generalization tests, manipulating the test stimuli in Phase 3 of a renewal procedure along a relevant dimension should yield a generalization gradient for renewal.

Studies of renewal arrange reinforcement, extinction, and testing across three successive phases (see Bouton et al., 2012, for a review). Testing in the third phase assesses how a change in the more global stimulus context controls responding. Stimulus conditions arranged during extinction and testing contexts arrange different configurations of stimuli similar to tests of stimulus generalization, but the assessment of context renewal differs because multiple stimulus dimensions differ qualitatively across the extinction and testing contexts (e.g., Bouton et al., 2011; Todd et al., 2012). In colloquial terms, researchers often 'throw in everything but the kitchen sink' when making the extinction and testing contexts different. As a result, renewal of responding in Phase 3 reflects only a single point of stimulus control along a range of possible of stimulus dimensions. Therefore, typical procedures used to assess renewal make it relatively difficult to assess precisely how variations in test stimuli control responding in Phase 3, and whether similar stimulus-control processes govern renewal as in studies of stimulus generalization. Methods grounded in traditional procedures to study stimulus control could contribute to understanding how stimulus control influences differences in magnitude between ABA and ABC renewal.

The present study used pigeons as subjects and assessed renewal with discrete stimuli across three phases by manipulating the frequency at which keylight colors alternated. During Phase 1, keylight colors alternated every 0.5 s for ten consecutive sessions. In Phase 2, we increased the frequency of alternation to every 0.13 s and extinguished responding. Finally, in Phase 3, we assessed a range of keylight-alternation frequencies within extinction sessions to assess a generalization gradient of responding. We predicted that renewal would be greatest either at S+ or at values beyond S+ shifted away from S− (i.e., peak shift).

Table 1
Frequency of keylight-color alternation in s and Hz during training and testing.

Training stimulus	Alternation frequency (s)	Hertz (Hz)
S−	0.13	3.85
	0.20	2.50
	0.32	1.56
S+	0.50	1.00
	0.78	0.64
	1.24	0.40
	1.96	0.25

Such findings would be consistent with those assessing generalization gradients employing typical procedures used to assess discriminative-stimulus control (e.g., Fox et al., 2013; Hanson, 1959). Moreover, such findings would suggest context renewal could be understood, at least in part, from principles governing stimulus generalization (e.g., Honig and Urciouli, 1981; Lazareva, 2012; Rilling, 1977 Lazareva, 2012; Rilling, 1977).

2. Method

2.1. Subjects and apparatus

Five homing pigeons, numbered 141–145, were used that had experience responding in concurrent-choice procedures but not with changes in keylight-alternation frequencies. They were individually housed and maintained at 85% ± 15 g of their free-feeding body weights with post-session supplementary feeding of mixed grain, as necessary. Water and grit were available at all times. The pigeons' home cages also served as the experimental chambers (see Podlesnik et al., 2012, for a detailed description). A response key could be transilluminated red and white. Pecks exceeding 0.1 N closed a microswitch. During hopper presentations of mixed grain, all key-lights were turned off, the hopper was raised and illuminated, and event timing was suspended. All experimental events were arranged and recorded by an IBM® PC-compatible computer running MED-PC IV® software. The colony room lighting was switched on at 00:00 and off at 16:00 daily. Sessions began at approximately, 4:00 am daily. No personnel entered the room while sessions were conducted.

2.2. Procedure

All sessions lasted approximately 19 min, excluding reinforcement time and were comprised of 28 discriminative-stimulus presentations (hereafter components). Components were 30 s in duration and preceded by a 10-s intercomponent interval (ICI), during which all lights were turned off. Reinforcement was arranged according to variable-interval (VI) 10-s schedules sampled without replacement from 13 intervals (Fleshler and Hoffman, 1962). In Phase 1, the keylight color alternated between red and white every 0.5 s (S+) and keypecking produced 2-s hopper presentations in all components for ten sessions. In Phase 2, the keylight color alternated every 0.13 s (S−) and responding was extinguished in all components for 6 sessions. In Phase 3, the keylight color changed across components quasirandomly while extinction remained in effect for 5 sessions. Across components, keylight colors alternated every .13, .20, .32, .50, .78, 1.24, and 1.96 s, selected from a list without replacement four times per session. Table 1 shows these keylight durations are logarithmically spaced (see Rilling, 1977) in Hertz. The keylight durations used were based on stimulus-flash rates from Fox et al. (2013) and pilot data collected in this laboratory.