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TRANSLATIONAL RESEARCH ON THE RELAPSE OF OPERANT BEHAVIOR

INVESTIGACIÓN DE TRADUCCIÓN SOBRE LA RECAÍDA DE LA CONDUCTA OPERANTE

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Abstract

Behavioral treatments for problem behavior arranging differential reinforcement can result in relapse due to a range of conditions. Basic research using nonhuman animal models in particular is useful because relevant behavioral processes can be revealed through systematic research that is impossible or unethical in clinical situations. Because relapse in clinical situations often will be determined by multiple factors, a range of preclinical animal models exists to isolate the influence of environmental events contributing to relapse. For example, resurgence procedures are ideal for assessing processes relevant to relapse due to failures in treatment integrity with differential–reinforcement treatments, which is common in clinical situations. We review our efforts to uncover fundamental behavioral processes underlying the *resurgence* of previously extinguished behavior upon extinguishing a more recently reinforced behavior. Furthermore, we use behavioral momentum theory and contextual control of behavior to provide different ways to understand the processes contributing to relapse and offer different avenues for mitigating relapse effects. Through the lenses of

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these frameworks, we assess the relative contribution of behavioral processes related to stimulus control, reinforcer control, and response competition to relapse. We suggest that translational research with a focus on first uncovering the fundamental behavioral processes underlying relapse processes are useful because they provide principled approaches to combating relapse in clinical situations.

Keywords: translational research, behavioral momentum theory, relapse, context renewal, resurgence, response competition

Resumen

Los tratamientos conductuales para la conducta problema en los que se emplea el reforzamiento diferencial pueden resultar en recaídas debido a una variedad de condiciones. La investigación básica en la cual se usan modelos animales no humanos en particular es útil debido a que los procesos conductuales relevantes pueden ser revelados a través de la investigación sistemática que es imposible o no ética en situaciones clínicas. Debido a que la recaída en situaciones clínicas frecuentemente estará determinada por múltiples factores, existe una variedad de modelos preclínicos con animales para aislar la influencia de eventos medioambientales que contribuyen a la recaída. Por ejemplo, los procedimientos de resurgimiento son ideales para evaluar los procesos relevantes a la recaída debida a los fracasos de la integridad del tratamiento con tratamientos de reforzamiento diferencial, lo cual es común en situaciones clínicas. Revisamos nuestros esfuerzos para revelar procesos conductuales fundamentales que subyacen el resurgimiento de conducta previamente extinguida tras extinguir una conducta reforzada más recientemente. Además, usamos la teoría de momento conductual y el control contextual de la conducta para proveer diferentes maneras de entender el proceso que contribuye a la recaída y ofrecemos diferentes vías para mitigar los efectos de la recaída. A través de estos marcos, evaluamos la contribución relativa de los procesos conductuales relacionados con el control del estímulo, el control del reforzador y la competencia de respuesta a la recaída. Sugerimos que las investigaciones de traducción enfocadas en revelar primero los procesos conductuales que subyacen los procesos de recaída son útiles porque proveen aproximaciones basadas en principios para combatir la recaída en situaciones clínicas.

Palabras clave: investigación de traducción, teoría del momento conductual, recaída, renovación del contexto, resurgimiento, competencia de la respuesta

Relapse is the recurrence of problem behavior following its elimination due to some kind of intervention (see Pritchard, Hoerger, & Mace, 2014a). Relapse is a major problem across many forms of problem behavior, including fear and anxiety (Vervliet, Craske, & Hermans, 2013), addictive behavior (e.g., drug abuse, gambling, overeating, paraphilia; O'Brien, 2005), and behavior dangerous to self and others in individuals with developmental disabilities (e.g., self–injury, aggression; Pritchard et al., 2014a). This problem behavior interferes with leading productive lives, engaging with family and community, and could even lead to death. Therefore, determining factors that can reduce the likelihood that problem behavior will relapse following treatment is important for individuals engaging in such behavior, their family, and society.

The best way to reduce the likelihood of relapse of problem behavior is to implement treatments targeting the variables that make relapse likely. Translational research can provide avenues to understand the fundamental learning processes underlying behavioral problems and then apply that knowledge to improving the efficacy of treatments through clinical research (see Mace & Critchfield, 2010). Translational research is defined as "the process of applying ideas, insights, and discoveries generated through basic scientific inquiry to the treatment or prevention of human disease" (World Health Organization, 2004, p. 141). Basic research with nonhuman animals offers the advantage of control over environmental and subject factors (i.e., experimental and genetic history of participants) and the opportunity to assess systematically and thoroughly the effects of a range of independent variables on relapse–analysis of variables influencing relapse often is impractical or unethical in clinical situations. Greater understanding of relevant behavioral processes can then provide principled, data–based reasons behind subsequent applied research and a rationale for clinicians adopting particular behavioral–treatment strategies.

Our research group uses translational research ranging from animal models to clinical application by focusing on understanding the relevance of fundamental behavioral processes for developing better behavioral treatments for problem behavior. Inherent in this goal is to determine approaches to reducing the likelihood of relapse of problem behavior. Although this research program is just getting started and we are continually shaping our approach, we describe our efforts using two specific frameworks to guide our research questions using both basic and applied research. We have been most influenced by behavioral momentum theory (see Nevin & Grace, 2000; Nevin & Shahan, 2011; Nevin & Wacker, 2013) and the role of contextual control over operant behavior (e.g., Bouton, 2004; Bouton, Winterbauer, & Todd, 2012). These two approaches differ in how they contribute to our understanding of how environmental variables influence relapse. Behavioral momentum theory is a quantitative theory primarily concerned with explaining how conditions of reinforcement determine the persistence and relapse of operant behavior. The role of contextual control, on the other hand, is a conceptual approach primarily concerned with how associations between stimulus contexts and operant contingencies modulate the performance of a response. We use both of these approaches to understand the factors involved in relapse and to develop approaches to improve the long–term effectiveness of behavioral treatments.

DRA Treatment and Resurgence

Behavioral treatments for problem behavior commonly arrange alternative sources of reinforcement contingent upon the absence of problem behavior and the production of appropriate behavior. These methods employ differential reinforcement to treat a broad range of problem behavior, from self–injury to drug abuse (Carr, Severtson, & Lepper, 2009; Higgins, Heil, & Sigmon, 2013; Petscher, Rey, & Bailey, 2009). Differential reinforcement of alternative behavior (DRA) is one of the most common treatments used for problem behavior. These DRA treatments include eliminating reinforcement contingent upon problem behavior. When in place, DRA treatments reduce the frequency of problem behavior (Petscher et al., 2009). However, the long–term maintenance of treatment efficacy is not nearly as well demonstrated. In a review of 116 articles implementing DRA treatment, Petcher et al. found only 28 articles reporting data on the long–term maintenance of treatment goals for reducing problem behavior following the primary treatment. Therefore, a concern is whether problem behavior returns, or relapses, when conditions change in some way. For example, treatment could be terminated, integrity could be compromised, and/or the context of treatment changed (e.g., transition from a treatment center to home or school). These conditions all present situations in which problem behavior could relapse despite DRA treatment initially eliminating problem behavior.

Relapse can occur due to a range of environmental events (see Bouton et al., 2012; Marchant, Li, & Shaham, 2014; Podlesnik & Shahan, 2010; Pritchard et al., 2014a, for reviews). Some learning theorists suggest all forms of relapse might be conceptualized within a single framework (e.g., Bouton et al., 2012; see section below on Contextual Control and Resurgence) but this debate is far from resolved (McConnell & Miller, 2014). In addition, the conditions producing relapse in laboratory conditions arrange different environmental stimuli and reinforcement contingencies so mitigating relapse in the clinic likely will require different strategies. We focus in this article primarily on understanding the factors contributing to relapse through the phenomenon called *resurgence*. Resurgence has been defined as the re–emergence of a previously reinforced and extinguished target behavior when a more recently reinforced alternative behavior is extinguished (Lieving & Lattal, 2003). Resurgence arguably is the behavioral phenomenon most obviously relevant to understanding factors contributing to long–term maintenance with treatments arranging differential reinforcement (e.g., DRA treatment). This observation is supported by the more frequent coverage of resurgence in journals of applied behavior analysis when compared to other relapse phenomena (e.g., context renewal, reinstatement, spontaneous recovery, etc.).

To demonstrate the basic procedures and findings from the study of resurgence, we describe one condition from an experiment of ours that is typical for the experimental and applied literature on resurgence (Podlesnik & Kelley, 2014). We assessed resurgence across three phases for pigeons pecking keys for food reinforcement. The left panel of Figure 1 shows this three–phase procedure, which is typical for assessing resurgence (see Pritchard et al., 2014a; we discuss the other manipulations later in this paper). During Phase 1, the target response key was green and reinforcement was arranged by a variable–interval (VI) 60–s schedule. Figure 2 shows mean response rates from Phase 1. Response rates were high during reinforcement of target responding during Phase 1 (closed circles). In Phase 2, target responding to the green key was extinguished, a side key was transilluminated red, and this alternative response was reinforced according to a VI 60–s schedule. Figure 2 shows that responding tracked the contingencies–target response rates decreased while alternative response rates immediately increased (open circles). In Phase 3, responding on both green and red keys was extinguished. The data in Figure 2 show that alternative response rates decreased during extinction as expected. However, target response rates re–emerged despite the continued absence of target reinforcement since beginning Phase 2. This re–emergence of target responding on the elimination of alternative reinforcement defines *resurgence*. Resurgence has been observed in a range of species from fish to humans under a wide range of experimental conditions (e.g., da Silva, Maxwell, & Lattal, 2014; Doughty, Cash, Finch, Holloway, & Wallington, 2010; Podlesnik, Jimenez–Gomez, & Shahan, 2006).

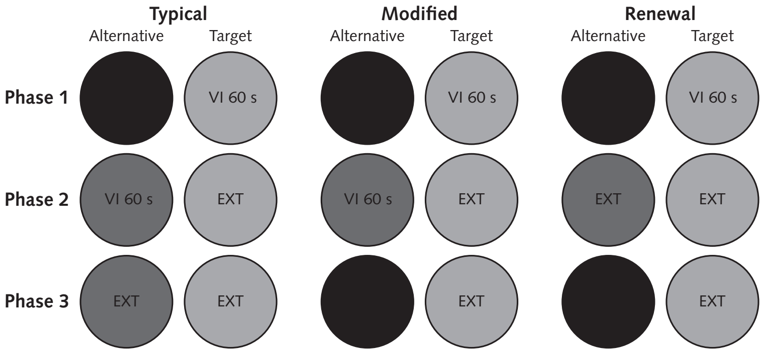

Figure 1. Resurgence procedures used by Podlesnik and Kelley (2014). Diagram of discriminative stimuli, reinforcement (VI 60 s), and extinction (EXT) of target and alternative responses across sessions of Phases 1, 2, and 3 of the Typical, Modified, and Renewal procedures. Target keys were lit green and alternative keys were lit red. Figure adapted from Podlesnik and Kelley (2014). (Copyright ©2014 by the Society for the Experimental Analysis of Behavior. Reproduced with permission.)

As previously mentioned, resurgence is particularly relevant for understanding relapse of problem behavior following treatments employing differential reinforcement. Specifically, reinforcement for target responding in Phase 1 is analogous to the reinforcement of problem behavior under natural conditions and during functional

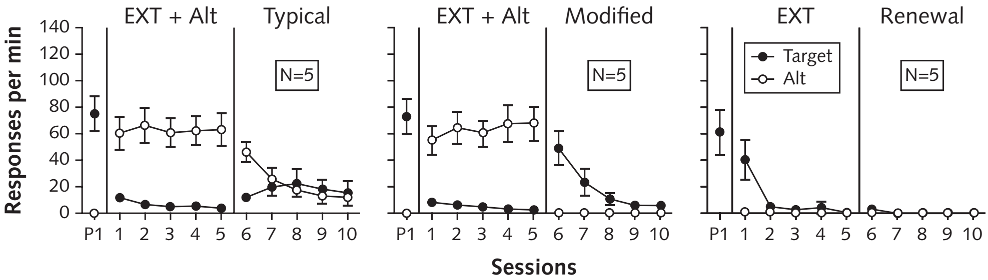

Figure 2. Findings from Podlesnik and Kelley (2014). Mean target and alternative (Alt) response rates during Phase 1 (P1), Phase 2 (EXT+Alt), and Phase 3 during the Typical, Modified, and Renewal procedures. Error bars indicate SEM. (Copyright ©2014 by the Society for the Experimental Analysis of Behavior. Reproduced with permission.)

analyses to determine the consequences maintaining problem behavior (e.g., Iwata, Dorsey, Silfer, Bauman, & Richman, 1982/1994). Phase 2 models treatments using differential reinforcement for eliminating problem behavior–reinforcing a functionally equivalent alternative behavior successfully eliminates problem behavior in a wide range of circumstances (see Petscher et al., 2009, for a review). Phase 3 is analogous to decreasing treatment integrity of the DRA treatment to the extent that all instances of the desirable alternative behavior go unreinforced. As with eliminating alternative reinforcement in Phase 3 of a resurgence procedure, nonreinforcement of an alternative desirable response would be expected to produce relapse of problem behavior. This is consistent with a number of studies of resurgence under conditions more closely resembling clinical situations (e.g., Lieving, Hagopian, Long, & O'Connor, 2004; Volkert, Lerman, Call, & Trosclair–Lasserre, 2009; Wacker, Harding, Berg, Lee, Schieltz, et al., 2011). Therefore, resurgence is a robust finding observed across a wide range of conditions in both preclinical and clinical situations.

We join many others in arguing for a greater understanding of the environmental factors producing resurgence and the relevance of resurgence to understanding relapse (see Lattal & St. Peter Pipkin, 2009; Marchant et al., 2014; Nevin & Wacker, 2013; Pritchard et al., 2014a). What follows is a discussion of how we have used two frameworks, behavioral momentum theory and contextual control, to examine the behavioral processes underlying resurgence and relapse processes in general. We provide evidence suggesting that neither framework alone appears to be sufficient to account for resurgence. However, both frameworks are useful because they provide different perspectives on the environmental variables contributing to resurgence. The ultimate goal of our work is to understand and exploit the behavioral processes that are most relevant to developing better and more durable behavioral treatments for problem behavior.

Behavioral Momentum Theory and Resurgence

Behavioral momentum theory is a quantitative theoretical framework that is in part concerned with how reinforcement variables affect the persistence and relapse of operant behavior. Most of the research evaluating the predictions of behavioral momentum theory has used nonhuman animals (see Nevin & Grace, 2000; Nevin & Shahan, 2011, for reviews). Importantly, many of the findings from the animal laboratory have been replicated with humans under experimental and natural conditions (e.g., Cohen, 1996; Mace, Lalli, Shea, Lalli, West, et al., 1990; see Dube, Ahearn, Lionello–DeNolf, & McIlvane, 2006; Nevin & Wacker, 2013; Pritchard et al., 2014a, for reviews).

A primary assertion of behavioral momentum theory is that all reinforcers within a discriminative–stimulus context function to increase the persistence and likelihood of relapse of all operant behavior within that context (Nevin & Shahan, 2011; Nevin & Wacker, 2013). Given this assertion, an important question is how differential–reinforcement treatments affect the rate of problem behavior versus its persistence and relapse. We have already discussed that treatments arranging differential reinforcement for an alternative response decrease the rate of problem behavior due to the prevailing reinforcement and extinction contingencies —this is the intended function of these treatments. Such findings in the context of behavioral momentum theory lead to the assertion that the *frequency* or *rate* of an operant behavior is governed by the operant relation between the target response and reinforcement in that situation, as described by the matching law (Herrnstein, 1970). Therefore, arranging alternative reinforcement either for a different response or independent from a target response decreases target response rate because those contingencies degrade the operant *response–reinforcer contingencies* for the target response. That is, target problem behavior decreases when all functionally equivalent reinforcers in a situation are not contingent on that target problem behavior.

Although differential–reinforcement contingencies can lead to low–rate problem behavior, problem behavior is nevertheless persistent and likely to relapse when treatment is challenged, such as when problems with treatment fidelity occur. According to behavioral momentum theory, these methods of arranging differential alternative reinforcement, either response independently (i.e., analogous to treatments using noncontingent reinforcement [NCR]) or contingent upon a different response (i.e., DRA), also serve another function. In treatments for problem behavior, the differential–reinforcement contingency typically arranges a higher rate of alternative reinforcers in the same situation as the target problem behavior. Specifically, the additional reinforcers increase the overall rate of reinforcement presented in the presence of the discriminative stimuli governing problem behavior. Much evidence suggests that higher reinforcement rates in the presence of discriminative–stimulus contexts increase the persistence and likelihood of relapse of all operant responses occurring in those contexts (see Nevin & Shahan, 2011; Podlesnik & Shahan, 2010; Podlesnik & DeLeon, 2015; Pritchard, Hoerger, Mace, Penney, & Harris, 2014b, for reviews).

Within the context of behavioral momentum theory, the resistance of a response in the face of a disruptive challenge (e.g., extinction, satiation, alternative reinforcement) defines persistence. Response rates decreasing little during disruption relative to the predisruption response rates are considered more *resistant to change* than responses decreasing to a greater extent relative to predisruption response rates. According to behavioral momentum theory, different processes govern response rates and resistance to disruption. Operant response–reinforcer relations govern the rate of behavior, as described above. Pavlovian *stimulus–reinforcer relations* govern resistance to disruption (see Nevin & Shahan, 2011). Thus, responses reinforced at a higher rate will be more resistant to disruption than responses reinforced at lower rates due to differences in Pavlovian stimulus–reinforcer relations. Specifically, the correlation between discriminative stimuli and reinforcement rate is what enhances resistance to disruption. Moreover, reinforcers increase resistance to disruption of operant behavior irrespective of whether those reinforcers are response dependent or occur independently of a target response. Furthermore, the same stimulus–reinforcer relations governing resistance to disruption also may govern the extent to which behavior will relapse. Following the elimination of target responding during disruption, greater reinforcement rates result in greater increases in target response rates (see Podlesnik & DeLeon, 2015; Pritchard et al., 2014a, for reviews). In the laboratory, responding typically is eliminated using an extinction procedure.

The processes governing response rates being separate from those governing the persistence and likelihood of relapse of behavior is a key assertion of behavioral momentum theory. The separate roles for the response–reinforcer and stimulus–reinforcer contingencies have been revealed across a range of studies to date (e.g., Mace, McComas, Mauro, Progar, Taylor, et al., 2010; Nevin, Tota, Torquato, & Shull, 1990; Podlesnik, Bai, & Elliffe, 2012; Podlesnik & Shahan, 2009, 2010; Pritchard et al., 2014b; Pyszczynski & Shahan, 2011). For example, Podlesnik and Shahan (2009) assessed resistance to extinction and relapse when pitting stimulus–reinforcer and response–reinforcer relations against one another in a test of resurgence. A Phase–1 baseline arranged equal variable–interval 120–s schedules of food reinforcement in the presence of both of two components of a multiple schedule with pigeons. A high rate of response–independent food reinforcers also was presented in one component according to a variable–time (VT) 20–s schedule. The top panel of Figure 3 shows that these added response–independent reinforcers increased the overall reinforcement rate in the presence of that discriminative stimulus compared to in the presence of the discriminative stimulus without added response–independent reinforcers. Thus, one keylight color served as a discriminative stimulus for the component with the overall greater reinforcement rate (hereafter termed the Rich component) and alternated with a different keylight color serving as a discriminative stimulus for the component with the lower reinforcement rate (hereafter termed the Lean component).

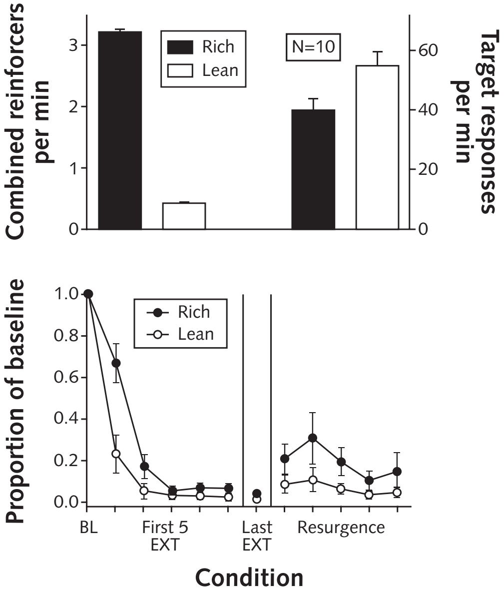

Figure 3. Findings from Podlesnik and Shahan (2009). The top panel shows the mean response-dependent and -independent food presentations per min during baseline on the left y-axis in the Rich and Lean components. The right y-axis shows mean responses per min during baseline in the Rich and Lean components. Error bars are SEM. The bottom panel shows the proportion of baseline (BL) response rates during successive sessions of extinction in the Rich and Lean components. (Copyright ©2009 by the Society for the Experimental Analysis of Behavior. Reproduced with permission.)

The top panel of Figure 3 also shows that target–key response rates were lower in the Rich component because the added reinforcement degraded the operant response–reinforcer relation, according to behavioral momentum theory. In Phase 2, Podlesnik and Shahan (2009) extinguished target–key responding in both components while reinforcing pecking to a newly illuminated alternative key according to a VI 30–s schedule in both the Rich and Lean components. While alternative response rates increased across sessions (data not shown), target responding decreased in both components. As the bottom panel of Figure 3 shows, responding in the Rich component persisted across extinction sessions to a greater extent than responding in the Lean component. Moreover, once response rates reached equal and near–zero rates in both components, Phase 3 assessed resurgence by removing the alternative reinforcement from both components, but maintaining all of the stimuli as in Phase 2 across the target and alternative keys.

The bottom panel of Figure 3 reveals that extinguishing alternative responding increased target responding in both components, but this increase was greater relative to predisruption rates in the Rich component compared to in the Lean component (absolute response rates were greater during resurgence for 8 out of 10 pigeons). Thus, increasing reinforcement rates, obtained by presenting additional response–independent reinforcement in the Rich component in Phase 1, resulted in greater persistence in Phase 2 and greater relapse in Phase 3 (see also Cançado, Abreu–Rodregues, & Aló, 2015, *this issue*, *but* cf. Cançado & Lattal, 2013; Fujimaki, Lattal, & Sakagami, 2015, *this issue*). Others have found similar effects of greater persistence and relapse by enhancing stimulus–reinforcer relations in a Rich component by (a) increasing response–contingent reinforcement rates for the target response in the Rich component (see Nevin et al., 1990; Mace et al., 1990; Podlesnik & Shahan, 2010), or (b) reinforcing a concurrently available response (see Nevin et al., 1990; Mace et al., 2010; Podlesnik et al., 2012). These findings support the assertions of behavioral momentum theory that operant response–reinforcer relations determine stable response rates (Phase 1) but Pavlovian stimulus–reinforcer relations determine persistence (Phase 2) and relapse (Phase 3).

The conclusion from these findings is that treatments arranging differential reinforcement (e.g., DRA, NCR) can ultimately contribute to the difficulty in treating problem behavior by increasing its persistence and likelihood of relapse. This counterintuitive finding has implications for behavioral treatments for problem behavior. These studies raise at least two points relevant to behavioral treatments arranging differential reinforcement. First, arranging greater rates of reinforcement during Phase 1 baselines of resurgence experiments produced greater resistance to disruption and relapse compared to lower reinforcement rates. The implication here is that differential reinforcement procedures could reduce problem behavior to low rates, but at the expense of producing persistent problem behavior that may relapse under a range of conditions (see Pritchard et al., 2014a, for a discussion). Presenting the alternative reinforcement in the same discriminative context as problem behavior, *even while extinguishing problem behavior*, is predicted by behavioral momentum theory to enhance the persistence and relapse of the problem behavior (see Nevin & Shahan, 2011; Nevin & Wacker, 2013; Podlesnik & DeLeon, 2015).

Second, reinforcing the alternative response while extinguishing target responding during Phase 2 initially decreased target responding but target responding resurged in Phase 3 when reinforcement for alternative responding was discontinued. Similar findings have been observed when arranging response–independent reinforcement during Phase 2 (see Doughty et al., 2007; Sweeney et al., 2014; Winterbauer & Bouton, 2010). Therefore, arranging alternative sources of reinforcement while extinguishing target problem behavior, as in Phase 2 above, could result in the resurgence of problem behavior if the treatment integrity becomes compromised through failure to present the alternative reinforcer. Moreover, the findings from Podlesnik and Shahan (2009) suggest the resurgence of problem behavior will be increased with a history of more frequent reinforcement.

Shahan and Sweeney (2011) developed a quantitative model of resurgence based on behavioral momentum theory that hypothesized: (a) Any alternative reinforcers arranged during reinforcement of target responding in Phase 1 of a resurgence procedure increase the strength of the target response; (b) Alternative reinforcement arranged during extinction of target responding in Phase 2 disrupts target responding; (c) Any alternative reinforcement arranged during extinction of target responding in Phase 2 also contributes to the strength of the target response; and (d) Removing the alternative reinforcement removes a disrupter of target behavior, thereby producing resurgence of target responding. Thus, alternative reinforcement can both strengthen and disrupt target responding.

Shahan and Sweeney's Equation 3 in their quantitative model is as follows:

$$\frac{B_t}{B_0} = 10^{\frac{-t(kR_a+c+dr)}{(r+R_a)^b}} \tag{1}$$

B_t is response rate time t in extinction and B_0 is training response rate (e.g., Phase 1). Terms in the numerator of the exponent contribute to the disruption of target responding relative to training response rates and the terms in the denominator contribute to countering those disruptive effects. During extinction of target responding, c is the effect of removing the contingency between responding and reinforcement, d scales the generalization decrement from eliminating the training reinforcement rate r as stimuli, and k scales the disruptive effect of alternative reinforcement R_a. Finally, b scales the response–strengthening effects of r and R_a on resistance to extinction and resurgence. Therefore, time in extinction increases the disruptive impact of terms in the numerator but is countered by all sources of reinforcement in the denominator. Equation 1 accounts for resurgence of target responding by setting R_a to the alternative reinforcement rate in Phase 2 and setting R_a *in the numerator* to zero when removing alternative reinforcement in Phase 3. Equation 1 has been used to describe resurgence across a range of experiments involving rats, pigeons, and children (e.g., Podlesnik and Shahan, 2009; see Shahan & Sweeney, 2011, for a review; Wacker et al., 2011).

Equation 1 expresses the role of *reinforcer control* in resurgence. Modifications to existing DRA–treatment strategies based on behavioral momentum theory likely will focus primarily on how to arrange reinforcement contingencies to mitigate resurgence (e.g., Sweeney & Shahan, 2013; Wacker et al., 2011). However, we now turn to another paradigm that provides a different and promising approach to understanding resurgence based on how changes in stimulus contexts govern behavior. Such studies of contextual control and relapse suggest a primary role for *stimulus control* underlying resurgence. A framework emphasizing stimulus control offers a different and perhaps complementary approach to devising treatment strategies for reducing the resurgence of problem behavior following DRA treatment.

Contextual Control and Resurgence

A different way resurgence has been explained is through changes in contextual stimulus control. Specifically, reinforcement and extinction contingencies form different stimulus contexts that contribute to the resurgence of previously reinforced behavior. Bouton and colleagues have suggested the way to understand resurgence is to examine a phenomenon suggested to be even more fundamental than resurgence —*context renewal* (e.g., Bouton, 2002, 2004; Bouton et al., 2012; Trask, Schepers, & Bouton, 2015, *this issue*, Winterbauer & Bouton, 2010). That is, resurgence occurs because of context renewal. Context renewal is defined as the re–emergence of a previously extinguished target behavior as a function of changing the stimulus context (Bouton et al., 2012).

Like resurgence, the procedure to assess context renewal typically arranges three successive phases. Unlike resurgence procedures that arrange changes in operant contingencies across successive phases, context renewal involves arranging stimulus contexts comprised of environmental stimuli that differ across the three phases (discussed in detail below). In Phase 1, an operant target response is reinforced under one set of contextual stimuli, Context A. In Phase 2, the target response is extinguished as the stimuli change to a novel context, B. In Phase 3, extinction remains in effect but the context either returns to Context A (i.e., ABA renewal) or transitions to a novel context, C (i.e., ABC renewal). Therefore, the contextual stimuli follow an ABA or ABC stimulus sequence while the contingencies follow an ABB sequence. Despite maintaining the extinction contingency between Phases 2 and 3, changing the contextual stimuli from B to either A or C produces reliable but transient increases in the target response rate (see Bouton et al., 2011; Todd, Winterbauer, & Bouton, 2012). Although ABA renewal typically is more robust than ABC renewal (but see Todd, 2013), both have been demonstrated (e.g., Berry, Sweeney, & Odum, 2014; Bouton, Todd, Vurbic, & Winterbauer, 2011; Todd et al., 2012; but see Zironi, Burattini, Aicardi, & Janak, 2006).

In ABA context renewal, Bouton et al. (2012) suggest that training a response during Phase 1 in Context A, and extinguishing that response during Phase 2 in Context B, produces ambiguity in the function of the response that is dependent on the context. According to Bouton et al., re–presenting Context A during Phase 3 following extinction in Context B retrieves the function, or "meaning," of responding established in Context A and increases responding (see Bouton & Todd, 2014; McConnell & Miller, 2014, for detailed accounts of recent research on contextual–control processes). Bouton et al. suggest this ambiguity in responding is similar to shouting the word 'fire' in the context of a movie theater versus a shooting range —as with operant responding above, the "meaning" of the word depends on the context. Relevant to understanding resurgence, the contextual approach conceptualizes the changes in reinforcement and extinction contingencies among the three phases of resurgence procedures as functioning identically as the aforementioned changes in the prevailing stimulus context across the three phases of context–renewal procedures (e.g., Bouton et al., 2012). That is, resurgence occurs because the contingency changes themselves serve as the relevant changes in stimulus context.

The features defining changes to a stimulus context across the three experimental phases during context renewal are not consistent across laboratories (see McConnell & Miller, 2014, for a discussion). For example, in studies of Pavlovian and operant conditioning with rats conducted by Bouton and colleagues, differences in contextual stimuli change across the three phases as a complex of olfactory, visual, location, and tactile cues within an experimental chamber (see Bouton & King, 1983; Bouton, Todd, Vurbic, & Winterbauer, 2011; Todd, Winterbauer, & Bouton, 2012; see also Laborda, Witnauer, & Miller, 2011). Changes in time between Pavlovian–conditioning trials among the three phases also produce context renewal in rats (Bouton & García–Gutiérrez, 2006). With pigeons, context renewal occurs when changing across phases the frequency in which a houselight flashes (Berry et al., 2014; Podlesnik & Shahan, 2009) or a keylight–color changes (Berry et al., 2014; Kelley, Liddon, Ribeiro, Greif, & Podlesnik, 2015; Kincaid, Lattal, & Spence, 2015). In studies with humans, contextual stimuli have been manipulated across phases through changes in the experimenter's shirt color and other surrounding experimental materials for children with developmental disabilities (Kelley et al., 2015), in testing room location, temperature, décor, lighting, and odor with university students (Collins & Brandon, 2002), and in room illumination only with university students (Vansteenwegen, Vervliet, Hermans, Beckers, Baeyens, & Eelen, 2006). Although these findings suggest the generality of context renewal, we know of no systematic attempts to determine, a priori, what defines a change in stimulus context. Instead, much research has focused on examining how variations in training and contextual variables influence the presence and size of the renewal effect (e.g., Berry et al., 2014; Bouton et al., 2011; Podlesnik & Shahan, 2009; Todd et al., 2012).

We assessed ABA context renewal first in pigeons and then with two children with developmental disabilities (Kelley, Liddon, Ribeiro, Greif, & Podlesnik, 2015). Table

1 shows the stimuli and contingencies arranged across two experiments. In Phase 1 of the experiment with six pigeons, a keylight alternated between red and white every .1 s while pecking produced food reinforcement according to a fixed–interval (FI) 10–s schedule. In Phase 2, the keylight alternated every .5 s and pecking was not reinforced (extinction). In Phase 3, the .1–s keylight–color alternation was reintroduced, but extinction remained in effect. In the experiment with the children, the stimuli were either yellow (Context A) or green (Context B), with context defined by the t–shirt worn by the therapist, a poster board on the wall in front of the participant, and task materials. Phase 1 involved FR 1 reinforcement with a highly preferred edible for number/letter tracing for one participant (John) and matching a picture card to a sample for the other (Drew). Extinction was in effect in Phases 2 and 3.

Table 1
Methods used in Kelley et al. (2015). Table reproduced from Kelley et al. (2015)

	Experiment 1	Experiment 2
Subjects	Pigeons	Children with autism
Responses	Key pecks	Mastered tasks
Stimuli	Key lights	Colors (tasks, placards, shirts)
Contexts	Key light flash rate	Context-specific colors
A	0.1 fps	Color 1
B	0.5 fps	Color 2
Contingencies	FI 10 s	FR 1
Reinforcers	2-s access to wheat	Preferred edibles
Design (contexts)	ABA	ABA
Design (contingencies)	ABB	ABB

Figure 4 shows responses per min across the three phases for the two experiments with pigeons and children from Kelley et al. (2015). In both experiments, reinforcement maintained responding during Phase 1 in Context A and extinction eliminated responding during Phase 2 in Context B. Returning to Context A in Phase 3 recovered the target response, which then decreased upon contacting the extinction contingency. These findings of ABA context renewal are relevant for behavioral treatments because problem behavior eliminated in a treatment setting can relapse upon returning to the original context in which problem behavior occurred (see Kelley et al., 2015; Pritchard et al., 2014a, for discussions).

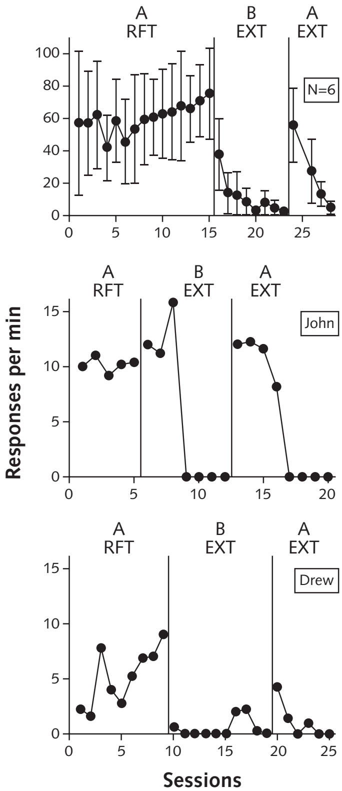

Figure 4. Findings from Kelley et al. (2015). All panels show mean target response rates across sessions of Phases 1, 2, and 3. Phase 1 arranged reinforcement (RFT) during Context A. Phase 2 arranged extinction (EXT) during Context B. Phase 3 arranged extinction (EXT) during Context A. The top panel shows responding in six pigeons. Error bars indicate SEM. The middle and bottom panels show responding across two children, John and Drew, respectively. (Copyright ©2015 by the Society for the Experimental Analysis of Behavior. Reproduced with permission.)

This analysis of contextual stimulus–control during resurgence has implications for using DRA to eliminate problem behavior across different settings. Eliminating problem behavior in a clinical setting could relapse when returning to an original nontreatment setting (i.e., ABA renewal) or transitioning to a novel nontreatement setting (i.e., ABC renewal). For example, problem behavior eliminated in a dedicated treatment facility might return upon returning to a familiar (e.g., home, school) or novel setting (e.g., a new group home). Strategies for reducing relapse during treatment by context renewal include (a) extinguishing the target response across multiple stimulus contexts in Phase 2 before transitioning across contexts in Phase 3 (e.g., Thomas, Larsen, & Ayres, 2003) and (b) adding features from the extinction Context B within the test for renewal in Context A during Phase 3 (e.g., Brooks & Bouton, 1994; Collins & Brandon, 2002; Willcocks & McNally, 2014).

Context renewal also is relevant to understanding resurgence. Bouton and colleagues (Bouton et al., 2012; Winterbauer & Bouton, 2010) suggested that resurgence is an instance of ABC context renewal. The transition to a novel Context C following reinforcement in Context A and extinction in Context B suggest *any* transition following the elimination of problem behavior in a treatment setting will be sufficient for problem behavior to relapse (e.g., Bouton et al., 2011; Todd et al., 2012). Specifically, Phase 1 of a resurgence procedure arranges reinforcement for the target response during one context, A. In Phase 2, extinguishing the target response while reinforcing the alternative response may be considered a novel context, B. Phase 3 introduces extinction for both target and alternative responses simultaneously. Because the simultaneous extinction of both target and alternative responses have never been arranged during either Phases 1 or 2, in Phase 3 they comprise another novel context, C. Bouton and colleagues suggest that these context changes alone may be sufficient to account for what has been called resurgence.

Although the strategies discussed above (e.g., Thomas et al., 2003; Collins & Brandon, 2002) that were developed from studies of contextual control of behavior are promising for reducing *context renewal*, the link between those treatment strategies have not been assessed in any detail in either preclinical or clinical studies relevant to the *resurgence* of problem behavior. With respect to resurgence following DRA–based treatment, it is important to consider the interactions between *reinforcer control* from behavioral momentum theory and *stimulus control* from studies of context renewal. We describe such an approach next.

Stimulus Control versus Reinforcer Control

Podlesnik and Kelley (2014) attempted to distinguish between reinforcer and stimulus control over the resurgence of operant behavior. We also tested Shahan and Sweeney's (2011) resurgence model (Equation 1) as an account of resurgence under different stimulus conditions. Pigeons' key pecking was reinforced with food according to VI 60–s schedules or pecking produced no programmed consequences across three phases. Figure 1 shows the three procedures arranging differences in stimulus and/or reinforcer conditions. In all three procedures, stimuli and contingencies for *target responding* were identical across all three phases. Phase 1 presented reinforcement for target responding on a green key, whereas Phases 2 and 3 arranged extinction for target responding. Figure 1 also shows that the differences across the three procedures were with the stimuli and contingencies arranged for the *alternative response*. The left panel of Figure 1 introduced this procedure in the DRA Treatments and Resurgence section when first describing resurgence arranged with standard methods (hereafter Typical procedure). In the Typical procedure, Phases 2 and 3 arranged reinforcement and extinction, respectively, of alternative responding in the presence of the red key. Therefore, the Typical procedure arranges for contingencies to change between Phases 2 and 3 but the antecedent stimulus conditions remained the same. The stimulus features of the Typical procedure differed from Phase 1 to Phases 2 and 3, while the contingencies changed across all three phases. In the center panel of Figure 1, the Modified procedure was identical to the Typical procedure except that the red keylight was off during Phase 3. The stimulus features of the Modified procedure were the same in Phases 1 and 3 and differed from Phase 2; the contingencies changed across all three Phases. As with the Modified procedure, the Renewal procedure arranged for the red keylight on the alternative key to be off in Phase 1, on during Phase 2, and off again in Phase 3. Importantly, reinforcement was not arranged for making the alternative response in Phase 2. As with procedures assessing ABA context renewal discussed above, the stimulus features of the Renewal procedure changed during Phase 2 while the reinforcement contingency in place in Phase 1 changed to extinction in Phases 2 and 3. Thus, the Renewal procedure follows the design of ABA context renewal procedures discussed above. Similarly to changing a context during Phase 2 with ABA context renewal, the Renewal procedure in this study assessed whether introducing the alternative stimulus only during Phase 2 could produce relapse. As noted below, this procedure serves as an important control to compare resurgence between the Typical and Modified procedures.

The different stimuli and contingencies arranged across phases with the different procedures shown in Figure 1 were used to assess whether resurgence in general is due to changes in stimulus or reinforcement conditions. The Typical and Modified procedures both arrange identical reinforcement and extinction contingencies but the stimulus conditions differed in Phase 3. Therefore, any difference in resurgence between procedures likely were due to differences in the stimulus features during Phase 3. Hereafter, we refer to the influence of stimulus conditions on relapse as *stimulus control*. If so, responding in Phase 3 of the Renewal procedure should be identical to responding in Phase 3 of the Modified procedure because stimulus conditions are identical between the Modified and Renewal procedures. Conversely, differences in relapse between the Modified and Renewal procedures would suggest that removing the differential–reinforcement contingency in place in Phase 2 of the Modified procedure also influenced relapse in Phase 3. Hereafter, we refer to the influence of the differential–reinforcement contingency on relapse as *reinforcer control*. Finally, differences in relapse among the three procedures would suggest the contribution of different processes governing the relapse effects across the three procedures.

Five pigeons were exposed to the Typical and Modified procedures in a counterbalanced order and five different pigeons were exposed to the Renewal procedure. Figure 2 shows mean response rates across the three phases for the three procedures (means were representative of individual performances). Reinforcement maintained target responding in Phase 1 for all three procedures. In Phase 2, alternative responding immediately increased as target responding decreased rapidly for both the Typical and Modified procedures. During the Renewal procedure, alternative responding did not increase reliably across the sessions of Phase 2 and target responding was greater during the first session than with the Typical and Modified procedures. In Phase 3, alternative responding declined gradually for the Typical procedure and was negligible in the Modified and Renewal procedures. Overall rates of target responding averaged across all Phase 3 sessions did not differ between the Typical and Modified procedures and were much greater than for the Renewal procedure. Most importantly, the patterns of target responding during Phase 3 differed across the three procedures. A bimodal pattern was observed for the Typical procedure, with target responding increasing and then decreasing across sessions of Phase 3. Although not the exclusive pattern observed in previous studies, this bimodal pattern has been observed frequently (e.g., Cançado & Lattal, 2011; da Silva, Maxwell, & Lattal, 2008; Doughty, da Silva, & Lattal, 2007; Leitenberg, Rawson, & Mulick, 1975; Lieving & Lattal, 2003; Podlesnik & Shahan, 2009, 2010). For the Modified procedure, target responding was greatest during the first session and declined gradually thereafter. For the Renewal procedure, target responding reliably but marginally increased for all five pigeons.

The different patterns of relapse across the three procedures suggest the influence of different behavioral processes. Simply removing the stimulus signaling the alternative response in Phase 3 of the Modified procedure more abruptly increased responding compared to the Typical procedure. In addition, the absence of a robust increase with the Renewal procedure suggests the difference in resurgence between the Typical and Modified procedures has relatively little to do with changes in stimulus control alone. It could be argued, however, that adding and removing the alternative reinforcement plus the keylight stimulus across Phases 2 and 3 of the Modified resurgence procedure produced a more drastic change in stimulus conditions than simply adding and removing the stimulus light in the Renewal procedure. Nevertheless, these findings question the conclusion that resurgence is simply an instance of ABC context renewal (cf. Bouton et al., 2012; Winterbauer & Bouton, 2010). Rather, they suggest a more nuanced relation between resurgence and renewal.

The different level of increases in responding between the Modified and Renewal procedures further suggests the role of *reinforcer control* by adding and removing the alternative reinforcement. Furthermore, another process appeared to also contribute to the more rapid increase in responding with the Modified procedure than with the Typical procedure. Specifically, the alternative response initially interfered with the production of the target response during Phase 3 of the Typical procedure —a process of *response competition*. Removing the alternative stimulus in the Modified procedure eliminated response competition by effectively removing the opportunity to engage in the alternative response entirely, as pigeons generally do not peck dark keys. Relatedly, presenting alternative reinforcement response independently, as opposed to response dependently, might also reduce response competition. Consistent with this suggestion, Doughty et al. (2007) observed increases the abruptness of resurgence relative to presenting alternative reinforcement response dependently (Doughty et al., 2007). Response–independent presentations might interfere less with target responding due to the absence of a reliable correlation between any specific response and reinforcement (see Baum, 2012, for a discussion) or the adventitious reinforcement of a response more compatible with alternative responding (see Skinner, 1948). Nevertheless, response competition in the form of the alternative response interfering with target responding appears to play a role in resurgence.

Fitting Shahan and Sweeney's (2011) quantitative model did not fully account for the different patterns of resurgence observed by Podlesnik and Kelley (2014). Figure 5 shows fits of Equation 1 to the mean findings from the Typical and Modified resurgence procedures. Response rates during Phases 2 and 3 are plotted as a proportion of response rates from the last six sessions of Phase 1 for the Typical and Modified procedures[1]. We used the experimental parameters to determine t, R_a, and r. Parameters c and k were free to vary. We fixed the d parameter to 0.001 and b to 0.5 because these values held constant in a range of experimental tests when they were free to vary (see Nevin, McLean, & Grace, 2001; Sweeney & Shahan, 2013). Figure 5 shows the c and k parameter estimates were within the range of previous studies, and the variance accounted for was acceptable but slightly lower than these previous studies (Nevin & Grace, 2005; Nevin et al., 2001; Shahan & Sweeney, 2011; Sweeney & Shahan, 2013). Nevertheless, the most salient feature of Figure 5 is the systematic deviation of the model fits from the actual resurgence data in Phase 3. Specifically, Equation 1 predicts a monotonic decrease from the initial increase upon initiating Phase 3. The bitonic increase and decrease in resurgence during the Typical procedure does not fit this pattern. Furthermore, resurgence conformed to a monotonic decreasing pattern with the Modified procedure but the function began higher and was steeper than predicted by Equation 1. The systematic deviation of the fits from

[1] We have not included fits of Equation 1 to the data from the Renewal procedure because there was little relapse to account for and there was no alternative reinforcement, Ra, arranged in the Renewal procedure.

the data for both of these procedures suggests that Equation 1 does not fully account for the behavioral processes in either procedure. It is particularly problematic for this model that it did not fully account for the very common pattern of data from the Typical procedure that resembled methods frequently used in both basic and applied studies of resurgence.

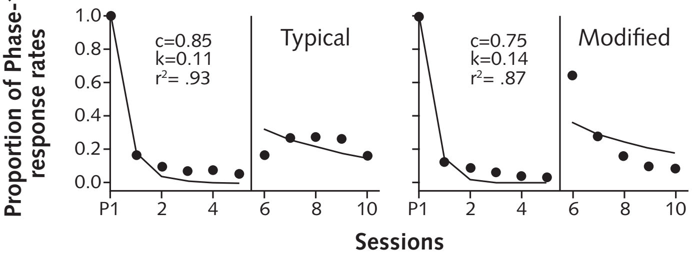

Figure 5. Quantitative analyses from Podlesnik and Kelley (2014). Least squares regression fits of Equation 1 to mean proportion of Phase 1 (P1) response rates across pigeons from the Typical and Modified resurgence procedures. Figure adapted from Podlesnik and Kelley (2014). (Copyright ©2014 by the Society for the Experimental Analysis of Behavior. Reproduced with permission.)

Shahan and Sweeney's (2011) model of resurgence (Equation 1) has been useful as a framework for revealing processes involved in resurgence. In addition, it also was useful in highlighting processes that likely will need to be accounted for with future theoretical development. Although more experimentation is needed, response competition and stimulus control are processes that should be considered in the development of models of resurgence.

An understanding of response competition has the potential to influence clinical interventions. A fairly common DRA arrangement includes the introduction of a response, such as a card exchange, that replaces the target behavior (e.g., Carr & Durand, 1985). Implicit in this arrangement is that the card will always be present to be exchanged. However, children may misplace or destroy the card, or caregivers may forget or lose the card. The loss of the stimulus is analogous to the Modified condition described above, in which the discriminative stimulus was turned off in Phase 3 (see also Wacker, Harding, Morgan, Berg, Schieltz, & Padilla, 2013). These results suggest that response patterns during resurgence may be different depending on the amount of competition between alternative and problem behavior. Whether nonreinforcement comes in the form of (a) extinction (card exchanges no longer produce the reinforcer) or (b) the inability to engage in a response that produces the reinforcer (because the card is not available) could influence when problem behavior re–emerges following DRA treatment.

Conclusion

Understanding the behavioral processes influencing whether problem behavior relapses after being eliminated by behavioral treatment offers the possibility that a return of problem behavior might not necessarily mean an entirely ineffective treatment. Instead, the challenge is to understand those processes contributing to relapse so behavioral treatments can be specifically designed to prepare for and mitigate the influence of those processes on relapse. For a related example, observing an increase in a problem behavior upon initiating an extinction procedure (i.e., extinction burst) would not suggest extinction is ineffective at decreasing problem behavior. On the contrary, it is a clear sign behavior has contacted the contingency and maintaining the extinction contingency will produce the desired effect of a further reduction in problem behavior. An understanding of extinction processes allows clinicians to expect such effects and offers the possibility to tailor treatment decisions at the source of the change in behavior. Our approach begins with the assumption that the best tools for eliminating relapse from behavioral treatments is to understand the behavioral processes underlying why relapse happens in the first place. Studies of the basic processes underlying relapse using animal models provides an effective way to assess these behavioral processes in a comprehensive and systematic way, without concerns over the ethical and practical issues that come with doing clinical research and treatment. Once the relevant behavioral processes are sufficiently well understood, those findings will provide principled reasons for designing and modifying interventions to be most effective.

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