

Chapter 12

Behavioral Momentum Theory: Understanding Persistence and Improving Treatment

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12.1 Introduction

Translational research in behavior analysis aims both to reveal the underlying principles governing behavior and to address society's behavioral problems. Translational research has been a part of behavior analysis for a long time (see Hake 1982). However, there has been a renewed focus on instigating collaboration among those primarily interested in questions of a basic scientific nature (i.e., basic researchers), those interested in developing and refining behavioral technology (i.e., applied researchers), and the practitioners employing behavioral technologies to treat behavior (see Mace and Critchfield 2010; Critchfield 2011). Mace and Critchfield suggest collaboration is essential to an effective translational program. Differences in training between basic researchers, applied researchers, and practitioners will mean different strengths and weaknesses in understanding fundamental processes underlying behavior and implementing behavioral techniques to change behavior meaningfully. Collaboration among individuals with training spanning the basic-to-applied continuum functions to fill knowledge gaps, which makes for more productive translational research that can satisfy interests of all involved.

Behavioral momentum theory is a quantitative framework that is particularly relevant to addressing questions of both basic and applied significance (see Nevin and Wacker 2013). Behavioral momentum theory attempts to understand how relations between environmental contexts and reinforcement come to influence behavioral persistence and relapse. With its roots firmly planted in the quantitative analysis of

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behavior (see Nevin 1992), there is plenty of experimental and theoretical development required to uncover the fundamental processes that govern behavioral persistence. Furthermore, the notion of behavioral persistence also is important to applied researchers and practitioners, as persistence and relapse of problem behavior are relevant to the maintenance of treatment goals (see Mace et al. 2010; Nevin and Wacker 2013). Persistent behavior is likely to continue despite disruption or distraction, which is important to understand regardless of whether the behavior of interest is problematic or desirable. Therefore, it is particularly fitting to have a chapter in this series on behavioral momentum theory and its relevance to the treatment of behavior in individuals diagnosed with autism spectrum disorder (ASD). The goals of this chapter are to (1) provide an overview of the conceptual, quantitative, and empirical background supporting the assertions of behavioral momentum theory; (2) address the relevance of behavioral momentum theory to understanding how common treatments for problem behavior might inadvertently enhance the persistence of problem behavior; and (3) evaluate a novel approach based on behavioral momentum theory to circumvent enhancing the persistence of problem behavior. Generating greater understanding of these areas through collaboration between basic and applied behavioral researchers will benefit the development of behavioral treatments for individuals diagnosed with ASD.

12.2 Reinforcement and Behavioral Momentum Theory

Behavior is a function of its consequences. Reinforcers are consequences that increase the frequency of behavior that reliably produces those consequences (Skinner 1938). The process of reinforcement has been studied for approximately 100 years (Thorndike 1911, 1913), and most of our understanding of how reinforcement affects behavior has been at the level of frequency: How does reinforcement influence how often organisms engage in a given behavior over some time frame? More frequent, larger, and less delayed reinforcers impact behavior more than less frequent, smaller, and more delayed reinforcers (see Davison and McCarthy 1988, for a review). Factors influencing the rate at which organisms engage in behavior are important to understand, but frequency is only one aspect of behavior. Behavioral momentum theory asserts that the effects of reinforcement are multidimensional (Nevin and Grace 2000).

According to behavioral momentum theory, reinforcement generates both velocity- and mass-like properties of behavior (see Nevin and Grace 2000, for a review). The velocity-like property is the generally well-understood effect reinforcement has on a behavior's frequency, or *response rate*. The mass-like property underlies factors influencing how persistent behavior is in the face of disrupting conditions (e.g., distraction, extinction, satiation), or *resistance to change*. Behavioral momentum theory asserts that, as velocity and mass are independent and empirically separable aspects of physical momentum, response rates and resistance to change are independent and separable aspects of behavioral momentum. The effects of forces that dis-

rupt behavior are inversely related to behavioral mass but independent of velocity. For present purposes, operations that either increase or decrease the rate of behavior do not necessarily have the same effect on its resistance to change.

The separable processes governing response rate and resistance to change lead to what might appear to be paradoxical and counterintuitive effects of reinforcement. Reinforcing a particular response in an environmental context (e.g., discriminative stimulus) increases the rate of that response and decreases all other responses. However, reinforcement also increases resistance to change of *all responses* in that environmental context, not only the response producing reinforcement. These different effects of reinforcement have very important implications for the treatment of problem behavior as conventionally arranged for individuals with ASD or other intellectual and developmental disabilities. Techniques proven to decrease problem behavior by arranging alternative sources of reinforcement could inadvertently make problem behavior more resistant to change and, even if eliminated, more likely to recur (i.e., relapse).

12.3 Basic Research: Resistance to Change

Behavioral momentum theory suggests that separate processes govern response rate and resistance to change within the *discriminated operant* (Nevin and Grace 2000). The discriminated operant is considered the fundamental unit of analysis in the science of behavior (Skinner 1969). Three terms comprise the discriminated operant: the antecedent discriminative-stimulus context (A), the behavior (B), and the reinforcing consequence (C). According to behavioral momentum theory, the operant relation between the behavior and reinforcement (i.e., B–C relation) determines response rates. Therefore, behavioral momentum theory predicts that introducing reinforcement either response independently or dependent on responses different from the target response will decrease the rate of target responding by degrading the B–C relation (see also Herrnstein 1970). Conversely, the relation between the antecedent-stimulus context and reinforcement (i.e., A–C relation) independently determines resistance to change. The A–C relation is hypothesized to be Pavlovian as it relates to the association between stimuli and consequence. Despite decreasing response rates, behavioral momentum theory asserts that additional sources of reinforcement introduced into a stimulus context will increase resistance to disruption of a target response by enhancing the A–C relation.

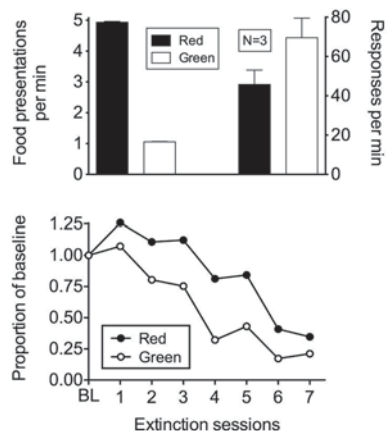
Nevin et al. (1990) directly pitted the B–C and A–C relations against one another and assessed their effects on response rates and resistance to change. They degraded the B–C relation but enhanced the A–C relation within a stimulus context by introducing additional reinforcers either response independently (experiment 1) or dependently when engaging in an alternative response (experiment 2). In both experiments, they arranged different antecedent discriminative-stimulus contexts that alternated and signaled different reinforcement conditions. They defined the stimulus contexts by presenting pigeons with disks, or keys, that could be illumi-

nated with different colors. Pecking the keys produced intermittent access to wheat as reinforcement.

In experiment 1, Nevin et al. (1990) alternated two stimulus contexts, signaled by red and green keys, and both were available for 3 min at a time. Pecking in both the red and green contexts (i.e., components) produced food reinforcement at an equal rate of 60 reinforcers/h, according to variable interval (VI) 60-s schedules of reinforcement. Specifically, reinforcers were made available every 60 s, on average, from the previous reinforcer presentation. Once a reinforcer was arranged, the next response produced the reinforcer. Although they arranged equal rates of response-dependent food reinforcement in the red and green components, they increased the overall food rate in the presence of the red keylight by presenting additional response-independent food reinforcers, according to variable-time (VT) schedules. The added response-independent food reinforcers impacted the B–C and A–C relations differently. First, the added food degraded the B–C relation in the presence of the red keylight because all food presentations were not dependent on keypecking (unlike in the green component). Second, the added food enhanced the A–C relation because the rate of food presentations increased in the presence of the red key relative to the green key. It is important to note that the increase in food presentations occurred despite the fact that response rates decreased in the presence of the red key. In an analogous treatment context, this would be akin to delivering response-independent reinforcers in the context in which the target behavior occurs. This would decrease levels of the target behavior in that context, but increase the overall amount of reinforcement delivered in that context.

Once baseline response rates reached stability, they assessed resistance to disruption in the presence of the two keylight colors. They assessed resistance to disruption by satiating the pigeons prior to sessions or eliminating all reinforcers from the components (i.e., extinction). To control for differences in baseline response rates, they expressed the decreases in response rates during disruption as a proportion of pre-disruption baseline response rates. The top panel of Fig. 12.1 shows the rates







Fig. 12.1 The *top* panel shows mean food presentations per minute during baseline on the *left y-axis* in the richer components signaled by the *red* keylight and the leaner components signaled by the *green* keylight. The *right y-axis* shows mean responses per minute during baseline in the *red* and *green* components. Error bars are SEM. The *bottom* panel shows the proportion of baseline (BL) response rates during successive sessions of extinction in the *red* and *green* components. Data originally reported in Nevin et al. (1990, experiment 1). SEM standard error of the mean



of food presentation (left *y*-axis) and baseline response rates (right *y*-axis) in the presence of the red and green keys from a single condition of Nevin et al. (1990, experiment 1). The added response-independent food enhanced the A–C relation by producing a fivefold greater reinforcement rate in the presence of the red key relative to the green key. The added response-independent reinforcement also degraded the B–C relation, as revealed by the decreased baseline response rates in the presence of the red key relative to the green key. The bottom panel of Fig. 12.1 shows greater resistance to disruption (i.e., higher levels of proportional responding during extinction) across seven sessions in the presence of the red key. Resistance to satiation revealed similar effects of greater persistence in the presence of the red key (see their Fig. 12.2). These findings are consistent with the predictions of behavioral momentum theory that separable processes govern behavior: Overall reinforcement rates (A–C relations), not baseline response rates (B–C relations), determine relative resistance to disruption between discriminative-stimulus contexts.

As in experiment 1 of Nevin et al. (1990), experiment 2 also revealed that an alternative source of reinforcement decreased baseline response rates but increased resistance to disruption of a target response in pigeons. However, experiment 2 arranged the additional source of reinforcement in one component to be dependent on engaging in a concurrently available response alternative. Figure 10.2 shows that the green and red components arranged equal rates of response-dependent food reinforcement on a right key, according to VI 240-s schedules (15/h). In the component signaled by the green keys, they also arranged a VI 80-s schedule presenting 45 reinforcers/h contingent on pecking the left key (i.e., total of 60/h from both keys). The additional response-dependent reinforcement decreased right-key baseline target response rates in the presence of the green keys relative to the red keys. Conversely, green-key target responding was more resistant to disruption by satiating the pigeons with pre-session feedings and extinguishing all reinforcement. Moreover, they found similar resistance to disruption of green-key target responding as

Fig. 12.2 The *left* panel shows components of the most basic quantitative relation between resistance to change and reinforcement rate in the presence of discriminative stimuli. The *right* panel shows that the effects of different values of sensitivity (*b*) in resistance to change alter both the difference between the functions and susceptibility to conditions of disruption

<u>Alternative</u>	<u>Target</u>	<u>Signaled food/hr</u>
 45	 15	60
 0	 15	15
 0	 60	60

in a third component that arranged 60 reinforcers/h entirely dependent on target responding from a VI 60-s schedule (i.e., white keys in Fig. 12.3). Thus, resistance to change was again a function of the overall reinforcement rate in the presence of a discriminative-stimulus context (i.e., A–C relations), not baseline response rates (i.e., B–C relations).

The findings from the two experiments in Nevin et al. (1990) provide strong support for the assertions of behavioral momentum theory. They revealed that enhancing the A–C relation increased resistance to disruption regardless of whether they degraded the B–C relation with additional response-independent or response-dependent reinforcement. Thus, the mass-like properties of behavior determined by reinforcement rates govern resistance to change and the velocity-like properties characterized by baseline response rates do not (see Podlesnik and Shahan 2008; McLean et al. 2012, for a discussion of exceptions).

The generality of these divergent effects of introducing additional sources of reinforcement on response rates and resistance to change has been established through replications in a range of experimental conditions and species, including goldfish (Igaki and Sakagami 2004), rats (e.g., Mauro and Mace 1996; Shull et al. 2001), and humans (e.g., Cohen 1996). In addition, several studies revealed similar effects when the alternative source of reinforcers differed qualitatively from those maintaining target responding (e.g., Grimes and Shull 2001; Shahan and Burke 2004). Finally, the overall rate of reinforcement also appears to govern resistance to change of cognitive processes in animal models of memory (Odum et al. 2005) and attention (Podlesnik et al. 2012b). Thus, the broad range of experimental evidence in support of behavioral momentum theory suggests generality in the A–C relation governing the persistence of behavior.

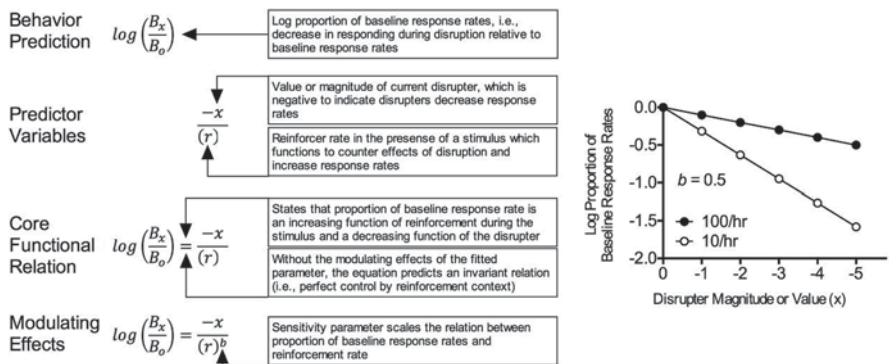


Fig. 12.3 Food reinforcers signaled per hour arranged according to VI schedules on the alternative (left) key and target (right) key across in Nevin et al. (1990, experiment 2). Three multiple-schedule components signaled by the different keylight colors were presented successively and alternated quasi-randomly. Total reinforcers per hour arranged across both keys in each component are shown on the right

12.4 Primer on Quantitative Analyses in Behavioral Momentum Theory

Although the quantitative analyses will not play a primary role in the present discussion, we provide a very basic introduction to these analyses because they play a fundamental role in directing basic research on behavioral momentum theory and in understanding how environmental variables affect behavioral persistence (see Nevin and Shahan 2011, for a detailed description of these quantitative analyses). Equation 12.1 displays the quantitative relation between resistance to change and the environmental variables influencing it, that is, the value or magnitude of disruption and the rate of reinforcement in the presence of a discriminative-stimulus context:

$$\log\left(\frac{B_x}{B_o}\right) = \frac{-x}{(r)^b}. \quad (12.1)$$

Figure 12.1 describes the relation between resistance to change and reinforcement rate from Eq. 12.1 in detail. As indicated in the left panel of Fig. 12.3, response rates during disruption, B_x , are expressed relative to stable baseline response rates, B_o . As seen in Fig. 12.1 showing data from Nevin et al. (1990), response rates during disruption are expressed relative to baseline response rates normalize any differences in baseline response rates. In many quantitative analyses, proportion of baseline response rates are expressed logarithmically (\log) and presented as a function of the magnitude or value of the disrupter (x). The value of x is negative because disrupters typically decrease response rates, and logarithms of fractions (e.g., the left side of Eq. 12.1) are negative. Thus, the \log of 1 is 0, and the \log of 0.5 is -0.3 . In reality, x values represent specific operations such as sessions of extinction or amount of food consumed prior to a session. The rate of reinforcement in the presence of the discriminative-stimulus context is shown as r . The b parameter scales the relation between \log proportion of baseline response rates and the reinforcement rate arranged in the presence of the discriminative stimulus. Note that b serves a similar function as the sensitivity parameter in the generalized matching law (see Chap. 6 in this volume).

The right panel of Fig. 12.3 shows hypothetical proportion of baseline data when baseline reinforcement rates were high at 100 reinforcers/h or lower at 10 reinforcers/h, which feed into r in Eq. 12.1. Greater reinforcement rates in the denominator are analogous to greater mass in physical momentum and produce greater resistance to disruption. Proportion of baseline is presented as a function of an increase in disrupter magnitude or value (x). Greater values of x in the numerator produce increasingly greater levels of disruption regardless of the baseline reinforcement rates. Increasing x is analogous to increasing the external force impacting a moving body in physical momentum. Empirical studies of resistance to change provide estimates of sensitivity to reinforcement (i.e., b) approximating 0.5 (see Nevin and Shahan 2011). Therefore, reinforcement impacts resistance to disruption at approximately half of its programmed value. Less sensitivity would reduce the

difference between the two functions, which would occur if the two discriminative-stimulus contexts were difficult to discriminate.

Variations of Eq. 12.1 direct research by providing a quantitative framework from which to devise additional experiments. For example, it is well known that disrupting behavior by extinguishing responding reduces responding not only by eliminating the response-reinforcer contingency but also by changing the stimulus conditions (e.g., Nevin et al. 2001). Extinction removes a very important stimulus to the organism (i.e., the reinforcer), and removing greater reinforcement rates changes the stimulus conditions more dramatically than removing lower reinforcement rates. Therefore, variations of Eq. 12.1 introduce additional parameters to the numerator to account for both removing the response-reinforcer contingency and changing the stimulus conditions (see Nevin and Grace 2000; Nevin and Shahan 2011). Experiments have supported such theoretical developments in accounting for a range of effects, including the well-known partial reinforcement extinction effect (PRE; see Nevin et al. 2001). Nevertheless, the present treatment of Eq. 12.1 should provide a basic understanding of how behavioral momentum theory quantifies the relation between resistance to change, reinforcement, and conditions of disruption.

12.5 Basic Research: Relapse

Recently, behavioral momentum theory has been extended to understand behavioral persistence more broadly. In addition to being resistant to disruption, behavior that is considered persistent also tends to be very likely to recur, or relapse, following apparently successful treatment (see Podlesnik and Shahan 2010; Winger et al. 2005, for discussions). From the perspective of a behavioral practitioner, once problem behavior has been reduced or eliminated, understanding how reinforcement conditions influence relapse is important for maintaining treatment goals across time and environmental contexts (see Mace et al. 2010, for a discussion). Given this relation between resistance to disruption and relapse, Podlesnik and Shahan (2009) assessed whether resistance to disruption and relapse were similarly a function of baseline reinforcement conditions (i.e., A–C relations). They arranged baseline conditions with pigeons similar to those from experiment 1 of Nevin et al. (1990). The VI 120-s schedules arranged 30 response-dependent food reinforcers per hour in both of two alternating components. They arranged an overall greater reinforcement rate in one component by providing an additional 180 response-independent reinforcers per hour, according to a VT 20-s schedule. As in Nevin et al., the added food produced lower baseline response rates but greater resistance to extinction in that component. Once response rates extinguished to similarly low levels in both components, they assessed whether the overall greater baseline reinforcement rate (i.e., enhanced A–C relation) also determined relative increases in responding from those low levels, that is, the amount of relapse.

Table 12.1 Basic descriptions of the three phases arranged in the reinstatement, resurgence, and renewal methods used to study relapse

Phase	Relapse method		
	Reinstatement	Resurgence	Renewal
1	Response-dependent reinforcement of target responding	Response-dependent reinforcement of target responding	Response-dependent reinforcement of target responding in context A
2	Extinction of target responding	Extinction of target responding and introduce reinforcement for alternative responding	Extinction of target responding in context B
3	Maintain extinction for target responding but introduce response-independent presentation of reinforcer maintaining responding in phase 1	Maintain extinction for target responding and introduce extinction for alternative responding	Maintain extinction for target responding and return to context A or introducing a novel context C

Podlesnik and Shahan (2009) arranged three methods frequently used to study relapse of extinguished operant responding in preclinical animal models of drug abuse; Table 12.1 shows a brief description of typical arrangements of these methods across three standard phases (see Bouton et al. 2012, for a review of these models). Following reinforcement of target responding in baseline (phase 1) and then extinction of response rates to similarly low levels in the two components (phase 2), they assessed relapse in phase 3 by (1) reinstatement: providing response-independent or response-dependent reinforcement during the first presentations of those components in a session, (2) resurgence: extinguishing a second response alternative that had provided reinforcement while extinguishing the target responses in both components, and (3) renewal: returning to the baseline environmental context after changing the environmental context upon initially introducing extinction. With all three methods, extinguished responding relapsed more in the component trained with the enhanced A–C relation. Therefore, resistance to extinction and relapse appeared to be determined similarly by the baseline rate of reinforcement trained in the presence of a discriminative-stimulus context. Moreover, behavioral momentum theory provides a quantitative account of reinforcement effects on resistance to extinction and relapse (see Podlesnik and Shahan 2010; Nevin and Shahan 2011, for reviews and quantitative modeling).

To provide an update to a review by Podlesnik and Shahan (2010), Fig. 12.4 plots the data from all existing studies examining the relation between resistance to extinction and relapse as a function of baseline A–C relations. We express both relapse and resistance to extinction as a difference between the mean log proportion of baseline response rates in the component arranging higher reinforcement rates (i.e., rich) minus the mean log proportion of baseline response rates in the component arranging lower reinforcement rates (i.e., lean). All data points represent means across

all subjects from different relapse data sets (see the figure caption for more details). Data sets from Podlesnik and Shahan (2009, 2010) appear as described in Podlesnik and Shahan (2010; see their Fig. 22). All data points were above 0.0 along the *x*- and *y*-axes, indicating richer baseline reinforcement conditions produced greater resistance to extinction and relapse than leaner reinforcement conditions across all studies. Relapse and resistance to extinction were correlated, according to a Pearson *r*, $r(17)=0.53, p=0.02$. Therefore, baseline A–C relations influenced relative resistance to extinction and relapse similarly between discriminative-stimulus contexts and in a manner consistent with behavioral momentum theory.

Figure 12.4 suggests that the effects of enhancing the A–C relation on resistance to change and relapse are robust and quite replicable when examined in the very controlled conditions of the laboratory with nonhuman animals. Most data sets used pigeons as subjects, with the exception of two obtained with rats (see Podlesnik and Shahan 2010; Pyszczynski and Shahan 2011). Still, applied investigators working with problem behavior also observe instances of reinstatement (DeLeon et al. 2005) and resurgence (Leiving et al. 2004; Volkert et al. 2004), while renewal is a conventional observation in many studies that examine extinction effects on problem behavior. It is important, therefore, to extend the generality of the relation between resistance to disruption and relapse, particularly with studies using human populations and in more natural environments. Such studies could provide a springboard for assessing strategies to minimize the reoccurrence of problem behavior once eliminated by treatment.

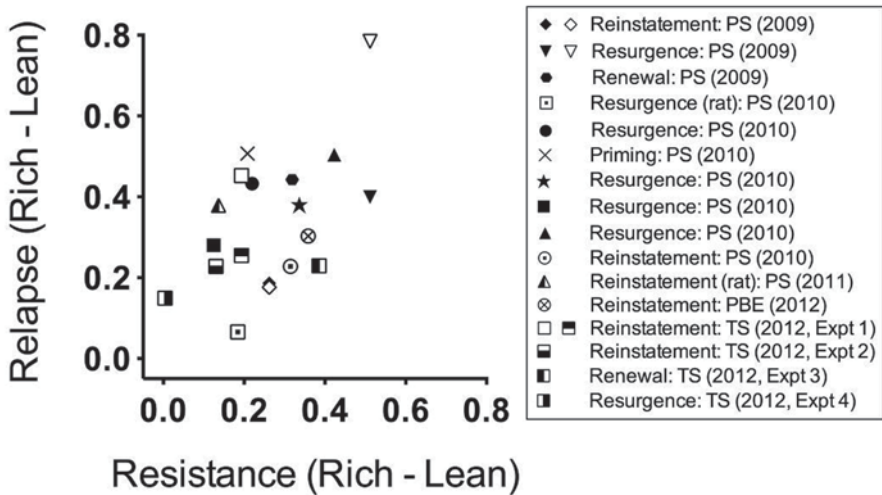


Fig. 12.4 Summary of studies assessing the relation between relapse and resistance to extinction in stimulus contexts arranging different reinforcement rates. Both relapse and resistance to extinction are plotted as the rich-to-lean difference between log mean proportions of baseline response rates: $\log(\text{rich}_{\text{extinction or relapse}}/\text{rich}_{\text{baseline}}) - \log(\text{lean}_{\text{extinction or relapse}}/\text{lean}_{\text{baseline}})$. Data are from Podlesnik and Shahan (2009, 2010), Pyszczynski and Shahan (2011), Podlesnik et al. (2012a), and Thrailkill and Shahan (2012). Adapted from Podlesnik and Shahan (2010)

12.6 Applied Implications

The importance of establishing the generality of the relation between resistance to disruption and relapse becomes particularly clear when considering treatment methods frequently used to decrease problem behavior. In fact, the basic research studies described above that introduce alternative response-independent or response-dependent sources of reinforcement resemble techniques frequently used by applied behavior analysts to decrease problem behavior. Noncontingent reinforcement (NCR) typically involves identifying and delivering the reinforcer that maintains problem behavior independently of the problem behavior (see Carr et al. 2009, for a review). Another common treatment is to reinforce a different, desirable behavior to replace problem behavior (differential reinforcement of alternative behavior or DRA; see Petscher et al. 2009, for a review). With NCR and DRA treatments, behavioral practitioners usually attempt to extinguish reinforcement contingent on problem behavior but this is not always possible or practical. For example, practitioners often have little control over reinforcement when the behavior thought to be reinforced by consequences that are not socially mediated (i.e., automatic reinforcement). Even when reinforcers are delivered by others, extinction is often impracticable, as when the relevant reinforcer is attention delivered by peers. Although NCR and DRA effectively decrease the frequency of a wide range of problem behavior in a range of populations, much less is known about how they affect resistance to disruption and relapse of problem behavior. Because of the procedural similarities between the basic procedures and behavioral treatments, and the implications for the persistence of problem behavior, it is important to understand how these behavioral treatments impact resistance to change and relapse.

To assess the effects of NCR on response levels and resistance to change, Ahearn et al. (2003) introduced NCR to decrease stereotypical behavior maintained by automatic reinforcement in three children diagnosed with ASD (see also Mace et al. 1990, for relevant findings). A preference assessment identified items to be presented to the children as the NCR treatment, according to VT schedules. The NCR treatments decreased the frequency of stereotypical behavior in most instances. After each NCR treatment, they assessed resistance to disruption by providing access to a different item that previously had been shown to decrease stereotypical behavior, while also measuring stereotypic behavior in the presence of these items during separate conditions that were not preceded by the NCR treatment. Consistent with the effects of added response-independent reinforcement in the basic laboratory (e.g., Nevin et al. 1990), resistance to disruption was greater in the test condition that followed NCR than during the test condition not preceded by NCR. Therefore, NCR treatments employed to decrease problem behavior ultimately make the problem behavior more resistant to disruption, consistent with the predictions of behavioral momentum theory.

One criticism could be offered that might initially assuage concerns over these potentially counterproductive effects of NCR. Specifically, it is true that problem behavior might be more persistent when assessed as a proportion of pre-disruption levels of responding. However, the pre-disruption decreases in problem behavior

through NCR treatment could, during disruption, result in lower absolute levels of problem behavior compared to the absence of NCR treatment. If this were the case, any increases in persistence of problem behavior with NCR treatment might be academic if absolute response rates before and during disruption were lower with NCR treatments. Despite finding that NCR treatment produced initially lower levels of stereotypy, Ahearn et al. (2003) found greater absolute levels of stereotypy during test conditions that followed NCR treatment (see also Mace et al. 1990; Grimes and Shull 2001, for related findings). Therefore, the very treatment designed to decrease problem behavior could ultimately produce more problem behavior overall if that behavior is disrupted or challenged in some way.

As with NCR treatments, DRA decreases problem behavior by introducing an alternative source of reinforcement in the same stimulus context as the problem behavior. Although DRA treatments effectively decrease problem behavior (see Petscher et al. 2009, for a review), the assertions of behavioral momentum theory have similar implications for treating problem behavior with DRA as with NCR: The additional reinforcement obtained by engaging in a desirable behavior could enhance the A–C relation and produce more persistent problem behavior.

Given these concerns, Mace et al. (2010) assessed whether DRA treatments used to decrease problem behavior in three individuals diagnosed with developmental disabilities might enhance resistance to disruption of that problem behavior. DRA treatments reinforced desirable behavior (appropriate toy play, requests for food), which decreased problem behavior (hair pulling/aggression, food stealing) compared to baseline conditions in which problem behavior was reinforced on schedules that varied across the individuals. These researchers assessed resistance to disruption of problem behavior following both the baseline condition and the DRA condition. They assessed resistance to extinction by eliminating all reinforcement obtained from the problem behavior by blocking attempts to engage in problem behavior, as well as discontinuing DRA, if in place. Relative to pre-extinction response rates, the added DRA produced greater resistance to disruption of problem behavior than the absence of DRA treatment. Extinction eliminated problem behavior in the absence of DRA within ten sessions in all three individuals but took approximately three times longer following DRA treatment. Moreover, absolute levels of problem behavior during extinction were greater with DRA treatment than in the absence of DRA treatment, consistent with the effects of NCR in Ahearn et al. (2003) discussed above. Therefore, DRA treatments decreased the rate of problem behavior, as designed, but increased its persistence beyond levels observed in the absence of any treatment at all.

The effects of NCR (Ahearn et al. 2003) and DRA (Mace et al. 2010) treatments on response rates and resistance to disruption of problem behavior are consistent with the effects of arranging alternative sources of response-independent or response-dependent reinforcement in the basic research studies (e.g., Nevin et al. 1990). According to behavioral momentum theory, these alternative sources of reinforcement initially decrease rates of problem behavior by degrading the B–C relation but increase resistance to disruption by enhancing the A–C relation (see Nevin and Grace 2000). An implication of these findings is that behavioral practitioners

should consider whether treatments designed to decrease problem behavior increase the overall rate of reinforcement in the context in which the problem behavior occurs. If so, the treatment could lead to more persistent problem behavior. Therefore, it might be necessary for practitioners to consider whether the benefits of initially decreasing problem behavior are worth the potential cost of producing more persistent problem behavior.

12.7 A Proposed Solution

The persistence-enhancing effects of adding alternative sources of reinforcement to a stimulus context generalize from the laboratory to more natural conditions. These effects have disconcerting implications for widely used treatments for decreasing problem behavior but are consistent with the assertions of behavioral momentum theory. Therefore, behavioral momentum theory could provide a framework from which to develop and evaluate novel treatment methods to circumvent enhancing the persistence of problem behavior (see also Nevin and Wacker 2013).

Mace et al. (2010) developed a potential solution to the persistence enhancing effects of DRA treatments based on an understanding of behavioral momentum theory. Specifically, adding alternative sources of reinforcement to the same stimulus context in which problem behavior is reinforced enhances its resistance to disruption. Therefore, novel treatment methods might circumvent the persistence-enhancing effects of DRA treatments by training alternative desirable behavior in contexts separate from those in which the problem behavior is reinforced. That is, reinforcing an alternative behavior in a different stimulus context from problem behavior might be an effective way to train an alternative behavior without enhancing the A–C relation in which the problem behavior occurs. Only once reinforcement establishes a well-trained alternative behavior in a separate stimulus context are the stimulus contexts mediating the alternative and problem behavior combined. Mace et al. reasoned that the training of the alternative behavior in a separate context from the problem behavior should produce less persistent problem behavior compared to reinforcing alternative and problem behavior in the same stimulus context.

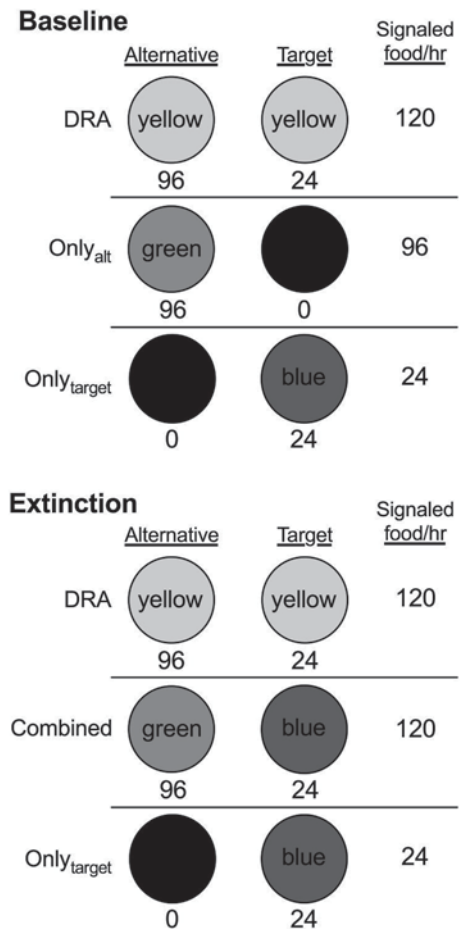
Mace et al. (2010) first assessed this potential solution to the persistence-enhancing effects of DRA treatments in an animal model with rats. They used an animal model prior to testing with a clinical population for two reasons. First, the animal model allowed them to arrange precise experimental conditions in which to test their hypothesis. Second, they wanted to refrain from extinguishing desirable behavior in a clinical population before knowing whether their novel approach might be effective.

Figure 12.5 diagrams the multiple schedules arranged by Mace et al. (2010) during baseline and extinction tests for four rats pressing levers for food reinforcement, according to VI schedules. In their study, lights above two levers flickered at different rates to signal the three different stimulus contexts that alternated throughout daily sessions (i.e., components). However, in Fig. 12.5, we substituted colors for

the differing flicker rates to facilitate comparisons to a different study arranging similar procedures by Podlesnik et al. (2012a), which is discussed below. During baseline (top panel), the DRA component modeled a standard DRA treatment, with an alternative response arranging 96 reinforcers/h in the same context as a target response arranging 24 reinforcers/h. The DRA component arranged 120 reinforcers/h overall between the alternative and target responses. The next two components modeled the training of alternative and problem behavior in separate stimulus contexts. The Only_{alt} component reinforced only the alternative response at a rate of 96/h. The Only_{target} component reinforced only the target response at a rate of 24/h. Consistent with the effects of DRA treatments, target response rates in the DRA component were lower than response rates in the Only_{target} component.

During extinction (bottom panel), Mace et al. (2010) combined the Only_{alt} and Only_{target} components that together signaled 120 reinforcers/h (i.e., combined component). The combined component, therefore, signaled an equivalent overall

Fig. 12.5 Food reinforcers signaled per hour on the left, alternative key and right, target key across stimulus contexts during baseline and a combined extinction test in Mace et al. (2010, experiments 2 and 3) and Podlesnik et al. (2012a). Total reinforcers signaled per hour across both keys in each stimulus context are shown on the right. Colors presented only in Podlesnik et al. (see text for details). *DRA* differential reinforcement of alternative behavior



reinforcement rate as that trained in the DRA component. The primary question was whether the persistence of target responding decreased when combining the stimulus contexts governing the separately trained alternative and target responses, relative to training the alternative and target responses together within the same stimulus context in the DRA component.

To assess differential resistance to extinction of target responding, Fig. 12.6 shows target response rates in extinction as a proportion of baseline response rates across blocks of extinction. Each block of extinction included one presentation of all three components quasi-randomly. In all four rats, target responding was more resistant to extinction in the DRA component compared to target responding in the combined component or presenting the Only_{target} component alone. Therefore, despite the DRA and combined components signaling equal overall reinforcement rates during extinction, training the alternative and target responses separately produced less resistance to extinction of target responding in the combined component than training those responses together in the DRA component.

Furthermore, Mace et al. (2010) found identical results in a clinical setting when applying these methods to decrease the persistence of disruptive behavior in two children diagnosed with developmental disabilities. Differently colored rooms and experimenters wearing differently colored hospital gowns signaled three components similar to those represented in the top panel of Fig. 12.5. Components alternated within daily sessions. In the DRA component, one experimenter negatively reinforced target responding, which was escape from demands, according to a VI

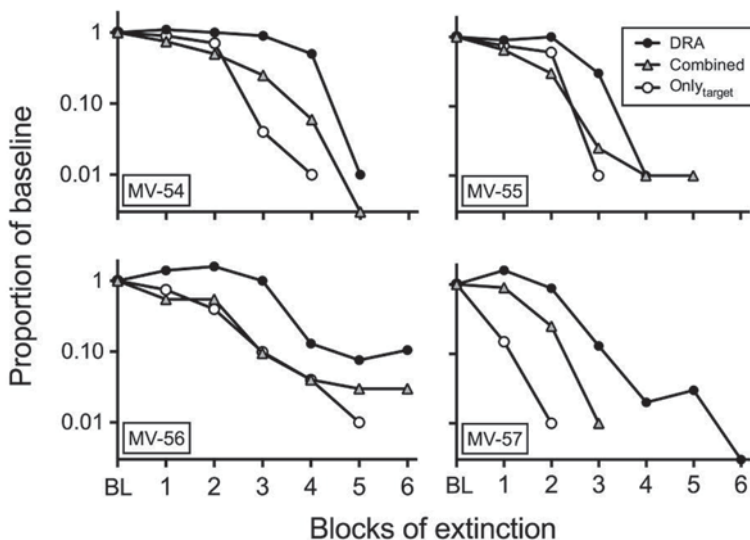


Fig. 12.6 Responding across successive blocks of extinction as a proportion of baseline (BL) response rates in three stimulus contexts. Data from four rats originally reported in Mace et al. (2010, experiment 2). Data points falling on the x-axis indicate proportion of baseline response rates below 0.001. Discontinued lines indicate no responses in those blocks of extinction. *DRA* differential reinforcement of alternative behavior

75-s schedule (i.e., 48 reinforcers/h). Another experimenter reinforced alternative desirable behavior through functional communication training (FCT; Carr and Durand 1985), according to a fixed-interval (FI) 20-s schedule (i.e., 180 reinforcers/h). The DRA component arranged 228 reinforcers/h overall. Target responding exclusively was reinforced in an Only_{target} component, according to a VI 75-s schedule (i.e., 48 reinforcers/h). Alternative responding exclusively was reinforced in a separate Only_{alt} component, according to an FI 20-s schedule (i.e., 180 reinforcers/h).

To combine stimulus contexts during extinction, the experimenters wore the colored gowns signaling the separately trained Only_{alt} and Only_{target} components within the room originally signaling only the Only_{target} component. During extinction, the combined component alternated with both the DRA and Only_{target} components. As in the animal models assessed by Mace et al. and Podlesnik et al. (2012a), combining stimuli from the separately trained Only_{alt} and Only_{target} components resulted in less persistent target behavior during extinction than target behavior trained in the DRA component. Therefore, this solution based on the predictions of behavioral momentum theory showed promise for reducing the persistence-enhancing effects of DRA treatments on problem behavior in a clinical setting.

12.8 Issues with the Proposed Solution

Two aspects of the findings from Mace et al. (2010) raise concern. First, during extinction, the Only_{target} component (represented by the blue key in Fig. 12.5) was presented both in the combined component and on its own, which is in twice as many components as the target stimulus from the DRA context. This additional exposure of the Only_{target} component to the extinction contingency might account for any differences in resistance to extinction of target responding between the combined and DRA components. Second, resistance to extinction of responding in the Only_{target} component was similar or greater in the presence of the combined component when compared to extinction of the Only_{target} component on its own. That is, training the Only_{alt} and the Only_{target} components separately and combining in extinction sometimes resulted in more persistent target responding than the simpler approach of extinguishing the target on its own. In other words, one might expect that the more complex approach should be more effective than simply extinguishing target responding, but it was not.

To address these concerns, the first author and colleagues replicated and extended the study by Mace et al. but with pigeons pecking keys for food reinforcement (Podlesnik et al. 2012a). Figure 12.5 (top panel) shows the baseline conditions that are similar to those arranged by Mace et al. (2010) in most respects. To address the concern that differences in target persistence were due exclusively to the Only_{target} component undergoing greater exposure to extinction, we arranged two extinction tests counterbalanced across six pigeons (bottom panel). One extinction test arranged the same test as Mace et al., as depicted in the bottom of Fig. 12.5, which included all three components. The second extinction

test controlled for exposure of target responding to extinction by presenting only the DRA and combined components in extinction and omitting the Only_{target} component. The extinction test presenting all three components decreased resistance to extinction of target responding in the combined component compared to presenting only the combined and DRA components. These findings suggest that exposing the Only_{target} component to extinction decreased target responding to that stimulus when presented in the combined component. Nevertheless, resistance to extinction of target responding was lower in the combined component than in the DRA component in both extinction tests. Thus, the decrease in resistance to extinction of target responding in the combined component relative to in the DRA component in Mace et al. likely was not exclusively a function of greater exposure of the Only_{target} component to extinction. Instead, these findings supported the conclusions of Mace et al. that reinforcing an alternative response in a separate component produces less persistent target responding compared to reinforcing both responses in the same component.

The second concern introduced above was that resistance to extinction of target responding in the combined component was similar or greater than simply extinguishing the Only_{target} component on its own. In Podlesnik et al. (2012a), we observed a different pattern—target responding consistently was less resistant to extinction in the combined component than the Only_{target} component presented on its own. From the perspective of developing treatment methods to decrease problem behavior, the preferred outcome would be greater decreases in target responding when combining the separately trained stimulus contexts than simply extinguishing target responding.

What explains the differences in the persistence in target responding with pigeons (Podlesnik et al. 2012a) versus rats and humans (Mace et al. 2010)? It is less likely that these differences can be attributed to species differences than to how discriminative contextual stimuli control behavior when combined (see Podlesnik et al. 2012a, for a detailed discussion). Specifically, a large body of evidence suggests that combining two separately trained discriminative stimuli can produce greater response rates than in the presence of either stimulus on its own. Exactly what modulates whether combining separately trained stimuli will produce increases or decreases in responding is complex and hotly debated (see Harris 2006). Nevertheless, a more general and important lesson can be gleaned for those considering implementing these stimulus-combining techniques. It is possible that combining separately trained stimulus contexts could result in more, not less, problem behavior. Practitioners considering implementing these techniques to decrease problem behavior should be aware of these potential effects (see DeLeon and Podlesnik, this volume). Clearly, integration of the existing literature examining how combining stimulus contexts influence behavior in studies conducted by applied behavior analysts would be useful to better understand how to implement these techniques most effectively. This gap in understanding the ways in which stimuli interact when combined to influence behavior is a rich area for basic and applied researchers to collaborate.

12.9 Extending These Findings

The previous section discusses the aim of Podlesnik et al. (2012a) that was to address the validity and generality of the findings of Mace et al. (2010). In addition, we extended the findings of Mace et al. by integrating the effects of combining separately trained stimulus contexts into the framework of behavioral momentum theory. We examined the role of training reinforcement rates on resistance to extinction and relapse.

First, in Podlesnik et al. (2012a), we also showed that the effectiveness of combining stimulus contexts on the persistence of target responding depended on one important variable already discussed at length—the overall baseline reinforcement rates obtained in the presence of a stimulus context (i.e., A–C relation). Within the same extinction test, we assessed the role of baseline reinforcement rates by combining the Only_{alt} component with both the Only_{target} component (24 reinforcers/h during baseline) and the target stimulus from the DRA component (120 reinforcers/h when summed across both responses). If the A–C relation determines the effectiveness of combining stimulus contexts on target responding, combining the same alternative context with target stimuli from both components should produce greater resistance to extinction of target responding in the overall richer DRA component than in the combined component.

Consistent with this hypothesis, introducing Only_{alt} component produced greater resistance to extinction of target responding in the DRA component than in the combined component. Thus, introducing an alternative stimulus context decreased the persistence of target responding as a function of the training context of reinforcement (i.e., A–C relation), consistent with the assertions of behavioral momentum theory. Moreover, the differential decrease in target responding as a function of the training context of reinforcement when combining stimulus contexts parallels the effects observed when disrupting responding with more typical disrupters (e.g., extinction, satiation). The effect of both combining stimuli and more traditional disrupters differentially disrupt behavior as a function of baseline A–C relations. Therefore, it appears that combining alternative stimulus contexts with target stimulus contexts can be conceptualized as disrupting target responding in the same ways as those more typical disrupters. That is, combining the alternative stimulus context with a target context acts an external force that disrupts target responding in a way that is inversely proportional to the mass of the target stimulus context.

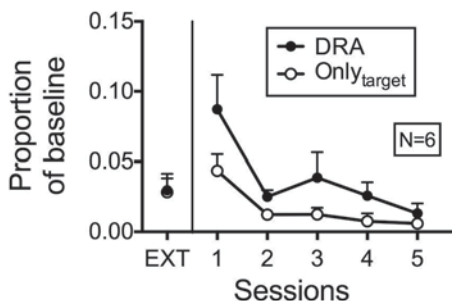
Second, we assessed whether the training A–C relations influence relapse of target responding when extinguishing with combined stimulus contexts. Given the relation between resistance to extinction and relapse described above (see Fig. 12.4), we reasoned that the relapse of target responding might also be a function of the baseline reinforcement rates across stimulus contexts. As previously mentioned, reinstatement is defined as relapse occurring as a result of re-presenting reinforcement after extinguishing baseline reinforcement (see Bouton et al. 2012, for a review). In Podlesnik et al. (2012a), we eliminated all reinforcement when presenting the combined and DRA components until target response rates reached similarly

low rates. In the next phase, response-independent food presentations during the first presentations of those contexts produced increases in both components. Consistent with the relation shown in Fig. 12.4, target responding reinstated more in the DRA component than in the combined component. Therefore, Podlesnik et al. revealed that combining separately trained stimulus contexts does not only produce less resistance to extinction of target responding than training stimulus contexts together but also results in less relapse. These findings suggest that training an alternative desirable behavior in a different context and combining with the context governing problem behavior could reduce the persistence of problem behavior in a general sense.

In addition, we assessed a novel method for examining relapse that is relevant to implementing these stimulus-combining techniques. As previously mentioned, resurgence is defined as the relapse of a previously extinguished response as a result of extinguishing a more recently reinforced response (see Podlesnik et al. 2006). Following extinction with the Only_{alt} component combined with both the target from the DRA component and the Only_{target} component (i.e., combined component), we asked whether removing the stimulus signaling the Only_{alt} component from both the DRA and combined components would produce a resurgence in target responding (i.e., restoring baseline stimulus contexts as shown in the top panel of Fig. 12.5). Furthermore, would resurgence be a function of baseline reinforcement rates (i.e., A–C relations)?

To assess relapse upon removing the Only_{alt} component from both the DRA and combined component, Fig. 12.7 shows responding as a proportion of baseline during the last extinction session with combined stimuli and five sessions with the stimulus contexts separated (unpublished data). Responding did not differ during the last extinction session but removing the Only_{alt} component produced relatively more responding in the DRA context. This finding was supported by a two-way repeated-measures analysis of variance (ANOVA), with significant main effects of component, $F(1,5) = 18.66$, $p = 0.008$, and session, $F(4,20) = 7.26$, $p = 0.001$. The increase in target responding was modest and brief but suggested that problem behavior could relapse when the stimuli no longer are presented in combination. Moreover, this relapse was more likely under the richer baseline training conditions of the DRA context. Therefore, these findings are consistent with previous findings that baseline reinforcement contexts similarly influence resistance to extinction and

Fig. 12.7 Responding as a proportion of baseline response rates in six pigeons during a final extinction (EXT) session and following the separation of the Only_{alt} stimulus from the DRA and Only_{target} contexts. Error bars are SEM. *DRA* differential reinforcement of alternative behavior



relapse and, therefore, with the assertions of behavioral momentum theory (see also Podlesnik and Shahan 2009, 2010). The implication of these findings is that practitioners implementing these techniques need to be aware that target responding could relapse if the context mediating the problem behavior is presented on its own after combining. Furthermore, this relapse would be especially likely in contexts arranging relatively high reinforcement rates.

12.10 How to Implement?

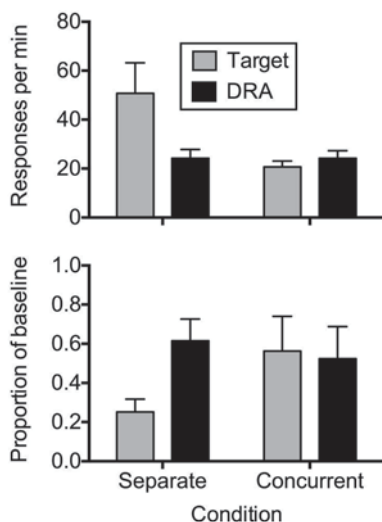
Combining a stimulus context mediating a desirable behavior with a context mediating a problem behavior provides a promising approach for decreasing the persistence of that problem behavior. However, many questions remain as to how these methods might be implemented by behavioral practitioners. For instance, combining the separately trained alternative and target stimulus contexts in extinction provides an invaluable theoretical test. Differences in resistance to extinction following separately versus concurrently trained alternative and target responses (1) indicate how those different training conditions influence persistence and (2) allow for those findings to be understood and incorporated within the framework of behavioral momentum theory. Nevertheless, do these tests for persistence with extinction realistically reflect how these techniques might be applied when treating problem behavior? It seems unlikely that practitioners would find it useful to extinguish desirable behavior so abruptly upon combining stimulus contexts. If introducing extinction when combining the contexts mediating alternative and problem behavior functions only as a theoretical test, what implications does this have for implementing treatments for problem behavior generally based on this approach? The two most obvious alternative approaches to introducing extinction when combining contexts mediating alternative and problem behavior are to continue to reinforce the alternative response and (1) allow any reinforcement contingent upon problem behavior to remain in place or (2) extinguish only the problem behavior. Both methods have implications for the persistence of problem behavior.

In the first case, training an alternative desirable response in a separate context would be followed by combining the contexts and maintaining reinforcement conditions for both the alternative and problem behavior. Practitioners use DRA treatments that continue reinforcement for problem behavior when extinguishing reinforcement for problem behavior is impossible, impractical, or unethical (see Petscher et al. 2009). Consistent with this manner of DRA treatment, combining the stimulus contexts likely would produce decreases in problem behavior. However, combining the stimulus contexts for an extended period would render those initially separate alternative and problem behavior contexts to be part of the same stimulus context. Behavioral momentum theory predicts that combining contexts this way ultimately would enhance the persistence of the problem behavior by enhancing the A–C relation.

Using the same six pigeons in Podlesnik et al. (2012a), Fig. 12.8 shows unpublished data supporting this prediction. The left bars in the top panel of Fig. 12.8 show baseline right-key target response rates when training the Only_{alt} and Only_{target} components in *separate* contexts (as described in the top panel of Fig. 12.5). Target response rates were greater than target response rates in the DRA component, modeling the presence versus absence of DRA treatment. Next, we combined the Only_{alt} and Only_{target} components as shown in the bottom panel of Fig. 12.5 but maintained reinforcement in both components for 21 sessions, modeling the presence of DRA treatment in both components. These data are shown as the concurrent condition in the right two bars of the top panel. Target response rates decreased to levels equal to target responding in the DRA component after combining with the alternative context. These findings were supported statistically with a two-way (condition \times component) repeated-measures ANOVA. Although we observed no statistical differences for main effects or interactions between condition and component, Sidak's multiple comparisons test showed a significant difference between components only in the separate condition, $t(5) = 3.30$, $p < 0.05$.

The bottom panel of Fig. 12.8 shows response rates during six consecutive sessions of pre-session feeding as a proportion of baseline target response rates in the separate and concurrent conditions. Training target responding (i.e., Only_{target}) in the absence of the alternative response in the separate condition resulted in less resistance to pre-session feeding compared to target responding in the DRA component. However, after combining the target and alternative stimulus contexts while maintaining reinforcement, resistance to disruption was similar between the target and DRA-target responding. Note that this increased persistence upon training the Only_{alt} and Only_{target} components together occurred despite differences in key color signaling the alternative and target responses. These findings also were supported statistically with a two-way (condition \times context) repeated-measures ANOVA. We

Fig. 12.8 The *top* panel shows right-key target responses per minute in the target and DRA contexts when training the Only_{alt} and Only_{target} stimuli from the target context separately (i.e., separate condition) and concurrently (i.e., concurrent condition). The *bottom* panel shows those responses as a proportion of baseline response rates following six consecutive sessions of pre-session feeding. *DRA* differential reinforcement of alternative behavior



observed a significant interaction between condition and context, $F(1,5)=6.73$, $p<0.05$, with a Sidak's multiple comparisons test revealing a significant difference in the separate condition, $t(5)=3.32$, $p<0.05$. These findings suggest that combining stimulus contexts and maintaining reinforcement conditions for alternative desirable and problem behavior would be similarly persistent compared to training the alternative and problem behavior in the same context from the beginning.

The other alternative to extinguishing both alternative and problem behavior when combining those stimulus contexts is to extinguish only the problem behavior. Extinguishing problem behavior while reinforcing an alternative behavior is largely consistent with the way in which practitioners implement DRA treatments, as long as extinguishing the problem behavior is possible, practical, and ethical (see Petscher et al. 2009, for a review). Petscher et al. suggest that DRA treatments implemented in this way are very effective at decreasing problem behavior. However, concerns arise that problem behavior could recur, or resurge, if the DRA treatment is discontinued or compromised in some way. For example, Volkert et al. (2004) demonstrated the resurgence of extinguished problem behavior in children when discontinuing or fading treatment with FCT (see also Lieving et al. 2004). Moreover, Podlesnik and Shahan (2009, 2010) showed that resurgence depends on A–C relations arranged during baseline conditions (see also Fig. 12.7). Therefore, resurgence of problem behavior is a concern if combining stimulus contexts and initially maintaining reinforcement only for the desirable alternative. Problem behavior could resurge if reinforcement for the alternative behavior is discontinued or, as often is the case, thinned over time (e.g., Hagopian et al. 2005).

Basic research and recent theoretical developments from the perspective of behavioral momentum theory are beginning to provide insights into how traditional DRA treatments might most effectively eliminate problem behavior in clinical situations (see Nevin and Wacker 2013). For instance, extended treatment with DRA results in less resurgence of problem behavior than brief treatments (Wacker et al. 2011). Nevertheless, highly reinforced problem behavior could be particularly resistant to treatment and likely to relapse. Determining how to incorporate the combination of alternative desirable stimulus contexts with those mediating problem behaviors could prove to enhance the effectiveness of existing treatments for problem behavior. The promise and potential pitfalls we have described reveal a ripe area for collaboration between basic and applied researchers to understand how best to implement these techniques.

12.11 Conclusion

Traditional behavioral treatments of NCR and DRA decrease problem behavior by arranging an alternative source of reinforcement (see Carr et al. 2009; Petscher et al. 2009, for reviews). Research in behavioral momentum reveals that these techniques can inadvertently increase the persistence of problem behavior (e.g., Ahearn et al. 2003; Mace et al. 2010). Therefore, Mace et al. proposed a novel method for

decreasing problem behavior grounded in the empirical and theoretical framework of behavioral momentum theory. If alternative and problem behavior reinforced in the same context enhances the persistence of problem behavior, reinforcing alternative behavior in a context separate from problem behavior should not enhance the persistence of problem behavior when combining both contexts. The findings from Mace et al. (2010) and Podlesnik et al. (2012a) provide initial support for exploring these methods further. Given the scarcity of research of these novel methods for decreasing problem behavior, however, many questions remain about how exactly to implement them. A substantial amount of research has developed some “best practices” for implementing more traditional NCR and DRA treatments over several decades (see Carr et al. 2009; Petscher et al. 2009, for reviews). Therefore, similar efforts probably are necessary to identify best practices for implementing these novel techniques for treating problem behavior. Translational research that employs the expertise of both basic and applied perspectives likely will be the most effective path forward.

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