

## CHAPTER 18

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# Resistance to Change from Bench to Bedside (and Back Again)

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Our everyday behavior often is faced with challenges. An individual with alcohol-use disorder, for example, may be discouraged from going to the bar by his family or could experience negative collateral effects of his drinking, such as loss of friends, vocation, or health. Likewise, a cross-country runner may encounter obstacles while training, such as fatigue, injury, or inhospitable weather conditions. While writing this chapter, our writing frequently was interrupted by the unique (and many) challenges posed by the global COVID-19 pandemic. Regardless of the behavior in question or the manner by which that behavior is disrupted, a likely outcome is that the behavior will persist despite the challenges that deter it. The individual with alcohol-use disorder might continue to intermittently consume alcohol despite pleas from loved ones to stop, and the cross-country runner might continue to train in the face of adversity.

The extent to which behavior persists when faced with a disruptor is termed *resistance to change* (Nevin, 1974), and this dimension of operant behavior is important for both practical and theoretical reasons. Understanding the factors that affect resistance to change may allow practitioners to increase resistance to change when it is a desirable attribute of behavior and decrease resistance to change when it is an undesirable attribute. Moreover, resistance to change is thought to reveal information about the way that reinforcement histories are carried forward in time to affect current behavior (see Nevin & Grace, 2000; Nevin et al., 1983) and the learning factors that lead to behavioral adaptation when reinforcement conditions change over time (Gallistel, 2012).

Perhaps unsurprisingly, resistance to change has been and continues to be a highly active area of research in behavior analysis. Much of the progress in this area has been made in the basic-research laboratory. Great strides also have been made, however, in translating findings from the basic research on resistance to change into real-world applications (for discussion, see Mace & Nevin, 2017; Nevin et al., 2016; Nevin & Shahan, 2011).

Our goal in this chapter is to provide readers with a broad overview of resistance to change. First, we discuss basic-research findings on this topic. In doing so, we describe the methods that are used to study resistance to change, how it is measured, and the variables that have been shown to reliably affect it. Next, we review translational and applied research on resistance to change, including some novel findings from clinical evaluations of resistance to change in the context of assessment and treatment of severe problem behavior. Finally, we describe behavioral momentum theory (Craig et al., 2014; Nevin et al., 1983; Podlesnik & DeLeon, 2015), the most widely applied conceptual analysis of resistance to change to date. We place special emphasis on the strengths, weaknesses, and practical utility of the theory. We close by detailing recommendations for practice based on the provided overview.

### Key Findings from Basic Research

Broadly speaking, resistance to change has been a topic of research within behavior analysis since its inception. Skinner (1956), for example, recounted an early empirical demonstration of operant extinction during his study of rats' lever pressing. The hopper that delivered food pellets, the consequence that maintained lever pressing, jammed. Despite the fact that lever pressing no longer produced food, the behavior did not cease immediately. Instead, rates of lever pressing gradually decreased with continued exposure to extinction contingencies (producing "a beautiful curve" on the cumulative record [Skinner, 1979, p. 95], as Skinner would later reflect in his autobiography). In this example, lever pressing initially persisted despite the fact that pressing no longer produced reinforcement, and the extent to which it persisted decreased as time in extinction increased. Examples of resistance to change like this one showed us *that* behavior resists change, but these examples told us little about *why* behavior resists change or the factors that are functionally related to resistance to change.

Nevin (1974) conducted a series of experiments that revolutionized the study of resistance to change and laid the foundation for research on this topic. In each of these experiments, Nevin studied pigeons' key pecking, and he arranged different conditions of reinforcement for key pecking using multiple schedules of reinforcement; that is, sometimes the pigeons' keys were lighted green and key pecking produced food reinforcers according to a specific schedule of reinforcement. Other times, the keys were lighted red and key pecking produced food reinforcers according to a different schedule of reinforcement. This multiple-schedule arrangement allowed Nevin to study the effects of different levels of an independent variable on behavior's resistance to change within subjects and during the same experimental condition. Nevin manipulated several variables between the multiple-schedule components across experiments, including the rate at which key pecking produced reinforcers, the overall rate of reinforcers (both response dependent and response independent), the magnitude of the reinforcer that was delivered contingently on key pecking, and the delay that separated key pecks from the reinforcers they produced. He also arranged several different tests of resistance to change, including extinction and delivery of response-independent food during the periods in between presentations of the multiple-schedule components (called *intercomponent intervals*; ICIs). Any operations that serve to change the rate at which ongoing operant behavior occurs, such as extinction, presentation of free reinforcers during ICIs, partial reinforcer satiation, and distraction from the operant task, have been termed *disruptors*, and we will provide examples of each below.

The key finding from Nevin's (1974) experiments was that resistance to change of key pecking tended to be greater in the multiple-schedule component that was associated with more valuable conditions of reinforcement. We use the word *value* here vis-à-vis the concatenated matching law (Baum, 1974; Baum & Rachlin, 1969): Higher rates of reinforcement are more valuable than lower rates, larger magnitudes of reinforcement are more valuable than smaller magnitudes, and more immediate reinforcement is more valuable than more delayed reinforcement. Thus, the multiple-schedule components that were associated with higher rates of, larger magnitudes of, or more immediate reinforcement across Nevin's experiments were also the components during which responding exhibited greater resistance to change.

This general finding, however, is by no means specific to Nevin's (1974) experiments. The effects of reinforcer *rate* on resistance to change have been particularly extensively studied, and many have replicated the positive relation between predisruption reinforcer rates and resistance to change with pigeon subjects (e.g., Bai & Podlesnik, 2017; Cohen et al., 1993; Craig et al., 2015, 2019; Nevin et al., 1990; Podlesnik & Shahan, 2009) and other nonhuman animal species including rats and fish (e.g., Blackman, 1968; Cohen, 1998; Cohen et al., 1993; Igaki & Sakagami, 2004; Pyszczynski & Shahan, 2011). As we see in the next section, these findings also have been replicated numerous times with human behavior exhibited by individuals with and without developmental disabilities. Still other studies have replicated the effects of reinforcer immediacy (e.g., Bell, 1999; Podlesnik et al., 2006) and magnitude (e.g., Harper & McLean, 1992; Rau et al., 1996; Shull & Grimes, 2006) on resistance to change in nonhuman animals, and more recent findings suggest that they are general to human behavior (e.g., McComas et al., 2008).

To understand why these variables may contribute to resistance to change, it is important to recognize that when reinforcers are delivered in a particular context, such as those arranged in multiple-schedule components, those reinforcers may have two effects. First, they may strengthen the operant response–reinforcer contingency in a manner that is consistent with the matching law (Herrnstein, 1961, 1970). Second, they may strengthen the Pavlovian stimulus–reinforcer contingency. Based on the findings so far reviewed, it is unclear which of these contingencies contributes to resistance to change. Nevin et al. (1990) conducted a series of experiments that addressed this interpretive issue.

In their Experiment 1, Nevin et al. (1990) trained pigeons to key-peck in a two-component multiple schedule across various conditions. When the key was green, key pecking produced food on average once per minute. The contingencies of reinforcement during red-key periods varied across conditions of the experiment. In one set of conditions, pecking the red key produced reinforcers, on average, once per minute; that is, the same contingencies were in place when the key was red as when it was green. In a second set of conditions, pecking the red key produced one reinforcer per minute, but additional reinforcers were delivered independently of key pecking. In a final set of conditions, the rate of peck-dependent and peck-independent reinforcer deliveries, when added together, equaled one reinforcer per minute. After each of these conditions, resistance to change of key pecking was assessed using pre-session feeding and extinction.

Nevin et al. (1990) reasoned that delivering peck-independent reinforcers in the red-key component should *weaken* the operant response–reinforcer contingency, because key pecks produced only a portion of the reinforcers that were delivered. Because those reinforcers were delivered in the presence of the discriminative stimulus (the red-key light), however, they should *strengthen* the Pavlovian contingency between the key light and the reinforcers that were delivered in its presence. If, on the one hand, resistance to change was a function of the response–reinforcer contingency, they expected delivery of

peck-independent reinforcers in the red-key component to *reduce* the resistance to change of key pecking. On the other hand, if the stimulus–reinforcer contingency governed resistance to change, they expected delivery of peck-independent reinforcers in the red-key component to *increase* the resistance to change of key pecking. Their findings aligned with the second of these possible outcomes: Resistance to change of key pecking during extinction and pre-session feeding tests was higher in the red-key component when that component arranged a higher overall rate of reinforcement than the green-key component. Moreover, resistance to change was about equal between components when they arranged the same overall rate of reinforcement. Other researchers have replicated and extended the findings from Nevin et al.'s (1990) Experiment 1 by showing that delivering response-independent reinforcers in a discriminative context increases resistance to change of a behavior in that context, even when the response-independent reinforcers are qualitatively different from response-dependent reinforcers (see Craig & Shahan, 2022; Grimes & Shull, 2001; Pyszczynski & Shahan, 2011; Shahan & Burke, 2004).

In a second experiment, Nevin et al. (1990) asked whether the Pavlovian stimulus–reinforcer relation in a multiple-schedule component could be strengthened, and the resistance to change of a behavior within that component could be increased, by adding reinforcers to the component contingently on a *different* response. Nevin et al. arranged a three-component multiple schedule. In each component, both a right key (hereafter the “target” key) and a left key (hereafter the “alternative” key) were illuminated, and the authors were interested in resistance to change of target-key pecking. When both keys were green, pecking the target key produced 15 reinforcers per hour, and pecking the alternative key produced 45 reinforcers per hour (for a total of 60 reinforcers per hour). When the keys were red, pecking the target key produced 15 reinforcers per hour, and pecks to the alternative key were placed on extinction. Finally, when the keys were white, pecking the target key produced 60 reinforcers per hour, and alternative key pecks were placed on extinction. Following a baseline phase, resistance to both extinction and pre-session feeding was assessed. Based on their findings from Experiment 1, Nevin et al. predicted that adding reinforcers for the alternative response in the green-key component should contribute to the resistance to change of the target response in that component. Their findings aligned precisely with that prediction. Resistance to change was the lowest in the red-key component in which 15 reinforcers per hour were delivered and about equal in the green- and white-key components that both arranged a total of 60 reinforcers per hour. Thus, in terms of contributing to resistance to change, neither the source of reinforcement nor the type of reinforcer appears to matter: So long as the reinforcer is delivered in the presence of a discriminative stimulus, it may enhance resistance to change of behavior in the presence of that stimulus. The relation between reinforcement conditions and resistance to change described above is ubiquitous and has been demonstrated in dozens of articles detailing research from the basic laboratory (see Nevin, 1992; Nevin & Grace, 2000). As we describe in the following section, a growing number of translational studies using human participants has replicated these findings and extended them in important ways.

## **An Overview of Translational and Applied Human Research**

The pipeline connecting basic-research findings to application in real-world settings sometimes is direct. For example, in 1928 while studying *Staphylococcus aureus* (a bacterium that is implicated in many common infectious diseases in humans), Alexander Fleming

found that mold spores prevented growth of his cultured bacteria. He had accidentally discovered penicillin, a finding for which he would later receive the Nobel Prize in 1945 (Fleming, 1929; see also Tan & Tatsumura, 2015). Shortly after Fleming's initial discovery in 1930, penicillin was used successfully to treat infections in humans (see Wainwright & Swan, 1986). Other times and often in the case of behavior-analytic research, the pipeline connecting seminal work in the laboratory to application is indirect: Intervening research often is dedicated to verifying that findings produced in the animal laboratory are general to humans and to less-controlled settings before that work is applied to socially significant behavior (for discussion, see Mace & Critchfield, 2010; McIlvane, 2009). Resistance to change followed the second of these two trajectories in its course from bench to bedside.

Mace et al. (1990) conducted an early example of translational research on resistance to change. In a two-part experiment, these researchers examined resistance to change of behavior exhibited by two adults with developmental disabilities. Mace et al. arranged a multiple schedule by having participants sort red and green utensils, the colors of which served as discriminative stimuli for each component. In Part 1 of the experiment, sorting was reinforced by delivering a small cup of coffee or popcorn according to a variable-interval (VI) 60 second schedule in one component and a VI 240 second schedule in the other. Following baseline, resistance to change was assessed by presenting a television program (i.e., Music Television [MTV]) as a disrupter across both components of the multiple schedule. Results showed that when the disrupter was presented, silverware sorting persisted to a greater extent in the component associated with the higher rate of reinforcement.

In Part 2 of the experiment, Mace et al. (1990) replicated Nevin et al.'s (1990) Experiment 1, which we described earlier. In one component of the multiple schedule, reinforcers were delivered for utensil sorting according to a VI 60 second schedule. In the other component, however, participants received reinforcers both dependent on and independent of utensil sorting according to VI 60 second and variable-time (VT) 30 second schedules, respectively. Then, as in Part 1 of the experiment, a television disrupter was presented to assess resistance to change of participants' utensil sorting. Responding was more persistent in the component of the multiple schedule that was associated with higher overall rates of reinforcement (i.e., the condition associated with both sorting-dependent and sorting-independent reinforcement). These findings were an important translational extension of those that had been observed previously in the basic laboratory. They demonstrated that, under multiple-schedule arrangements, higher rates of reinforcement engender greater resistance to change of human behavior, regardless of whether those reinforcers are delivered contingently on the behavior in question.

In addition to rate of reinforcement, McComas et al. (2008) demonstrated that reinforcer magnitude can also influence resistance to change of human behavior under multiple-schedule arrangements. Four graduate students participated and were required to play a simple computer game by clicking on colored shapes to produce points as reinforcers. These points were exchangeable for actual money (i.e., \$0.10 or \$0.05 per point) after participation. A two-component multiple schedule was arranged. In both components, two squares (one on the left and one on the right of the computer screen) were presented, and the components were signaled by the color of the squares (i.e., yellow or green). Responding to the left and right squares produced different magnitudes of reinforcement both within and across components; that is, in the yellow component, right clicks resulted in 1 point and left clicks resulted in 8 points according to a VI 30 second schedule. In the green component, right clicks resulted in 1 point and left clicks resulted in 2 points, again according to a VI 30 second schedule. After responding had stabilized,

resistance to change of square clicking was assessed by suspending point delivery. During this extinction test, three of the four participants most frequently clicked on the left square, which was associated with larger magnitudes of reinforcement, in both of the components. Of those three participants, two of them showed greater resistance to change in the yellow component, which was associated with the larger reinforcer magnitude. These findings suggest that, like Nevin's (1974) pigeons, resistance to change of human behavior may be affected by dimensions of reinforcement beyond simply the rate of its delivery.

In addition, as the study of resistance to change approached the "bed" side of the bench-to-bedside continuum, researchers began to consider additional variables that often are used in real-world settings and that may affect resistance to change. For example, Vargo and Ringdahl (2015) compared the effects of conditioned versus unconditioned reinforcers on the resistance to change with which preschoolers performed various tasks (i.e., number tracing, letter tracing, stringing beads). Unconditioned reinforcers were food items, and conditioned reinforcers were tokens exchangeable for food items. Preliminary assessments showed that both consequences served as reinforcers for task completion and were equally preferred by participants. Next, Vargo and Ringdahl arranged a two-component multiple schedule, wherein the components were signaled by the color of the task materials. During baseline conditions, task completion produced unconditioned reinforcers in one component according to a VI 30 second schedule and conditioned reinforcers in the other according to a VI 30 second schedule. Following baseline conditions, task completion was disrupted in three different ways: extinction, pre-session exposure to reinforcers, and distraction by presenting access to preferred movies. Results of this study varied depending on the disruptor that was used to challenge task completion, but Vargo and Ringdahl reported systematic outcomes across participants for each disruptor. Specifically, conditioned reinforcers produced greater resistance to change relative to unconditioned reinforcers when task completion was disrupted with either extinction or distraction. When task completion was challenged by pre-session exposure to reinforcers, however, unconditioned reinforcers produced greater resistance to change relative to conditioned reinforcers.

Leon et al. (2016) also evaluated differences between the effects of conditioned and unconditioned reinforcers on resistance to change. Specifically, they studied the task completion of children with intellectual and developmental disabilities (IDD) when completion produced either food (unconditioned reinforcers) or tokens later exchangeable for food (conditioned reinforcers). Resistance to change of task completion was assessed by progressively increasing the delay between reinforced responses and the delivery of the conditioned or unconditioned reinforcers. Results indicated that unconditioned reinforcers produced greater resistance to change in the face of reinforcer delays than conditioned reinforcers. Unlike Vargo and Ringdahl (2015), Leon et al. (2016) did not assess participants' preferences for unconditioned versus conditioned reinforcers. Therefore, it is possible that participants' preferences may have differentially affected resistance to change; that is, participants may have preferred food reinforcers over token reinforcers, and this difference in reinforcer quality may have been responsible for the differential outcomes obtained. This interpretation aligns with research reported by Mace et al. (1997) that demonstrated higher-quality reinforcers produced greater resistance to change of compliance with demands than did lower-quality reinforcers in children with IDD.

Collectively, the studies reported here show that many of the same variables Nevin (1974) found to impact resistance to change in basic studies conducted with nonhuman subjects impact the behavior of human participants in a similar manner. Given that the

goals of many behavioral interventions include (1) quickly reducing problem behavior and (2) developing or supporting appropriate alternative responses, understanding the variables that affect resistance to change continues to be an important focus of basic and translational research. Broadening our understanding of these variables may allow applied researchers to determine whether those same variables impact resistance to change of socially relevant, clinically important behavior. Furthermore, this information provides practitioners with a toolkit of treatment manipulations that may support the resistance to change of socially appropriate behavior and deter the resistance to change of socially inappropriate behavior.

Compared to basic and translational analyses, applied analyses of resistance to change are less numerous. A growing number of studies, however, have been conducted in the context of treatments for problem behavior in individuals diagnosed with IDD. We next turn to this literature, as it provides an important initial demonstration of the utility of the basic and translational research on resistance to change so far evaluated.

### **Extensions to Treatments for Problem Behavior**

Mace et al. (2010) conducted a groundbreaking study that provided an example of how not only basic and translational research on resistance to change can meaningfully inform treatments for problem behavior but also how translational research methods can be leveraged to overcome barriers to treatment. For our present purposes, we describe outcomes from their Experiment 1, which offered a point of contact between basic research and clinical work. We discuss in a later section outcomes from their Experiments 2 and 3, which demonstrate the utility of translational research as a means to solve real-world problems.

In their Experiment 1, Mace et al. (2010) examined resistance to change during clinical treatment of problem behavior (e.g., aggression, self-injurious behavior [SIB], food stealing) for three children diagnosed with IDD. Following a baseline condition in which a target problem behavior was reinforced, each child was exposed to two different conditions in a counterbalanced sequence. In one condition, the arranged treatment was differential reinforcement of alternative behavior (DRA) in which problem behavior continued to produce reinforcement as in baseline, but engaging in an alternative behavior (e.g., appropriate toy play, appropriate requests for food) provided a better condition of reinforcement. For example, one participant (Tom) gained access to preferred snack foods contingent on food stealing (target behavior) during baseline. When the DRA treatment was implemented, food stealing continued to be reinforced, but appropriate requests also produced access to preferred snacks and therapist praise. Then, to examine resistance to change, all responses were placed on extinction. In the second condition that followed baseline, participants' problem behavior was placed on extinction immediately, without intervening exposure to the DRA-based treatment.

For two of the three participants, problem behavior was suppressed when it was exposed to the DRA treatment. Interestingly, however, all three participants' problem behavior was more persistent during extinction that followed DRA compared to extinction that followed baseline. One may be tempted to come to the conclusion, then, that DRA-based interventions increase the future resistance to change of the behavior they are arranged to treat. It is important to remember, however, that Mace et al. (2010) continued to reinforce problem behavior during the DRA treatment and they provided comparatively high-quality reinforcers for the alternative behavior. Thus, it may not be the case that DRA per se results in increased resistance to change of problem behavior.

Instead, and consistently with previous research from the laboratory (Nevin et al., 1990, Experiment 2) the *subjectively better conditions of reinforcement* arranged during the DRA treatment may have been the causal variable that increased resistance to extinction.

Wacker et al. (2011) also illustrated the clinical implications of the previously reviewed basic- and translational-research findings by evaluating the resistance to change of both problem behavior (SIB, aggression, property destruction) and adaptive behavior (task completion, communication) within the context of clinical treatment. To do so, the authors repeatedly challenged treatment in a number of ways over the course of several months. Eight children diagnosed with IDD who engaged in problem behavior participated. All experimental procedures took place in the participants' homes, with their parents serving as treatment agents.

The study was comprised of four phases (Wacker et al., 2011). In the first phase, a functional analysis (Iwata et al., 1982, 1994) was conducted to determine the consequences that reinforced and maintained participants' problem behavior. The results from this phase indicated that each participant's problem behavior was maintained, at least in part, by escaping demands. This function subsequently was targeted for treatment. In the second phase of the study, a series of initial extinction sessions was arranged to evaluate the occurrence of problem behavior and adaptive behavior in the absence of reinforcement. The majority of participants displayed elevated levels of problem behavior similar to those observed during the functional analysis. Thus, problem behavior was initially highly resistant to change in the face of extinction. Next, in the third phase, Wacker et al. conducted functional communication training (FCT; Carr & Durand, 1985) while problem behavior was placed on extinction. To facilitate completion of work during the course of treatment, Wacker et al. provided functional reinforcement (escape from demands) for engaging in a communication response (in this case, depressing a micro-switch) only after participants met individualized work criteria. Throughout the FCT phase, extinction probes were conducted periodically to evaluate the relative resistance to change of problem and adaptive behavior over the long-term course of treatment. This phase continued until, during probe sessions, adaptive behavior (i.e., compliance and functional communication) persisted and problem behavior did not recur to baseline levels. In the final phase of their study, Wacker et al. arranged four unique challenges to treatment: (1) extended extinction sessions, (2) introduction of new demand materials, (3) removal of communication devices, and (4) a mixed schedule of reinforcement wherein adaptive and problem behavior produced reinforcement.

Wacker et al. (2011) found that FCT produced rapid suppression of problem behavior and increases in adaptive behavior. During the extinction probes, however, problem behavior was likely to recur. Over repeated exposures to extinction, the effects of treatment eventually persisted; that is, participants became more likely to continue to engage in compliance and communication and less likely to engage in problem behavior across probes. Strikingly, the remaining challenges to treatment that were arranged in the final phase of the experiment produced only mild disruptions in behavior, suggesting that the enhanced resistance to change of treatment effects that Wacker et al. observed across probe sessions generalized to other situations that might act to disrupt those effects. Overall, these findings translate and extend those from the laboratory by demonstrating that behavior that has been reinforced in the past is likely to demonstrate resistance to change, and the extent to which behavior persists may be a function of an organism's recent experiences (see Craig et al., 2015); that is, as the duration of an individual's history of reinforcement for engaging in a behavior increases, resistance to change of that behavior may increase. Conversely, as an individual's history of extinction for engaging



in a behavior increases, resistance to change of that behavior may decrease. It is important to note, however, that the jury is still out on the robustness of these functional relations, as the outcome from a growing number of basic-research studies have demonstrated weak or null effects of treatment duration on resistance to change (e.g., Nall et al., 2017; Shahan et al., 2020).

Several additional studies have demonstrated the influence of reinforcement-schedule variables on socially important and/or clinically relevant appropriate behavior. For example, Romani et al. (2016) evaluated how reinforcement rate impacted the resistance to change of problem behavior displayed by three children. Participants' problem behavior had been demonstrated to be sensitive to negative reinforcement in the form of escape from demands. During intervention, the researchers arranged a two-component multiple schedule, in which both of the components were associated with different reinforcement rates. Compliance produced reinforcement in both components according to the same VI schedule (the mean inter-reinforcer interval of which differed between participants), but the rate of reinforcement was increased in one of the components by delivering additional reinforcers according to fixed-time (FT) schedules (the mean inter-reinforcer interval of which also differed between participants). After compliance stabilized in both components, reinforcement was discontinued. Results demonstrated that compliance in the schedule component with the higher reinforcement rate (i.e., VI plus FT) was more resistant to change than compliance exhibited during the schedule component with the lower reinforcement rate (i.e., VI only).

In addition to reinforcement variables related to *treatment*, at least two published studies have evaluated how reinforcement rate during *assessment* impacts subsequent resistance to change during extinction. Lerman et al. (1996) compared rates of problem behavior during extinction following exposure to continuous-reinforcement (CRF) schedules and intermittent schedules during baseline. Specifically, the problem behavior of three adults diagnosed with IDD first was maintained during baseline by delivering reinforcers identified during functional analyses according to a CRF schedule. Behavior then was placed on extinction. Next, problem behavior was reestablished under an intermittent reinforcement schedule, followed again by extinction. When extinction patterns were compared across applications for an individual, results indicated that behavior persisted to a greater degree following the CRF baseline than following the intermittent-reinforcement baseline for two of the three participants when expressed as proportion-of-baseline responding.<sup>1</sup> For the third participant, proportion-of-baseline responding during the initial extinction sessions was greater following CRF than following intermittent reinforcement. Subsequently, however, proportion of baseline dropped to near-zero rates more quickly in extinction following CRF than in extinction following the intermittent reinforcement schedule. Given that the CRF baseline produced a higher rate of reinforcement than the intermittent-schedule baseline, these findings are in line with findings from the basic literature regarding the relation between reinforcement history and resistance to change.

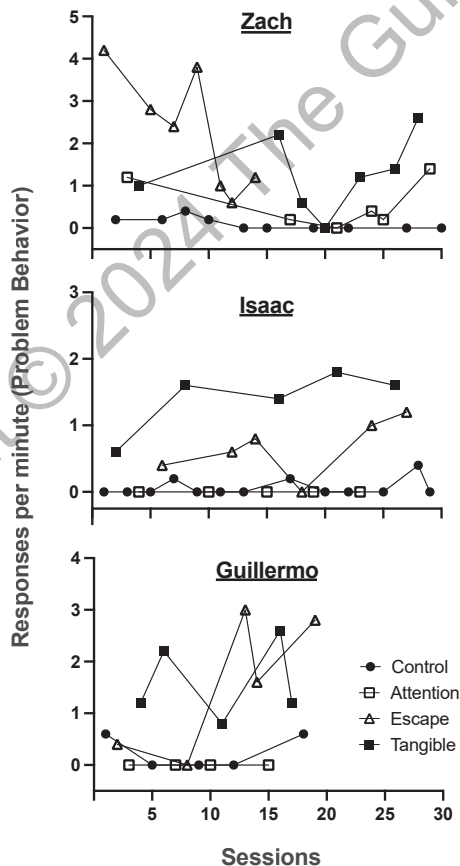
MacDonald et al. (2013) replicated the findings from Lerman et al. (1996) by comparing responding during extinction that followed either CRF or intermittent reinforcement

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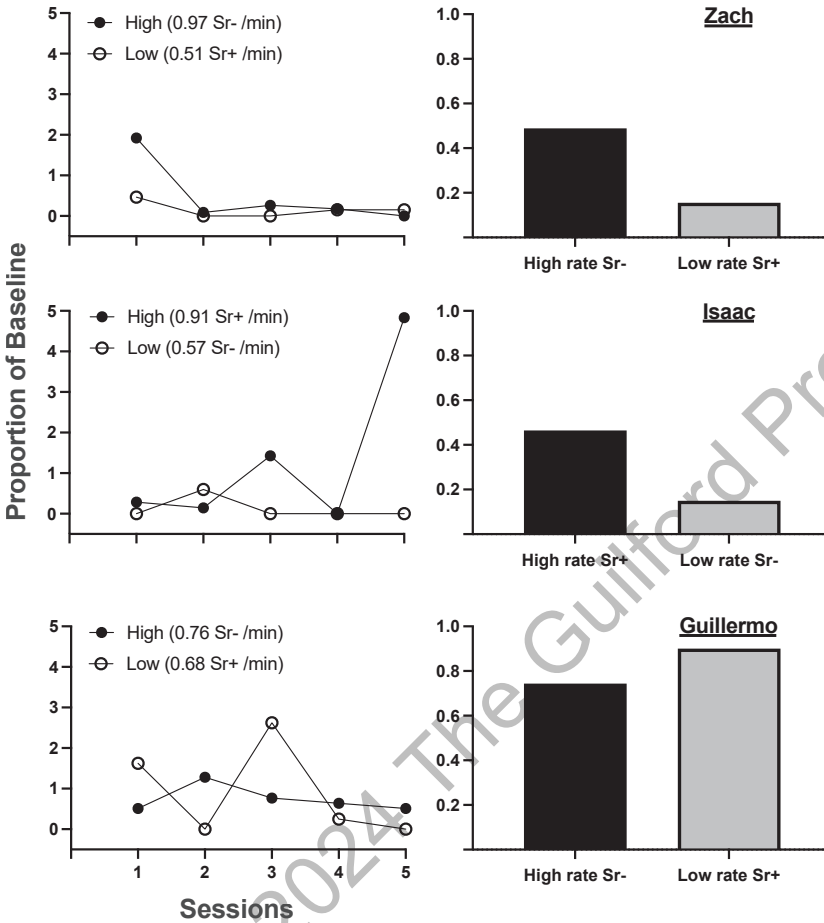
<sup>1</sup>The *proportion-of-baseline response rate* is a measure of resistance to change that is helpful when comparing resistance produced by different conditions of reinforcement. Frequently, different conditions of reinforcement produce differences in response rate during baseline. Proportion of baseline allows one to visualize between-condition differences in the slope of resistance-to-change functions independently of differences in the functions' intercepts.

schedules during functional analyses of problem behavior exhibited by four children diagnosed with IDD. The CRF schedules produced higher reinforcement rates compared to the intermittent reinforcement schedules. Subsequent responding during extinction persisted to a greater extent following CRF than following intermittent reinforcement. Again, these results align with findings from the basic literature (e.g., Nevin, 1974), in that responding preceded by higher reinforcement rates was more resistant to change than responding preceded by lower reinforcement rates.

In addition to these published studies, a series of unpublished datasets from Ringdahl's laboratory at the University of Georgia shows a similar phenomenon. Specifically, we evaluated the data from three individuals whose clinical cases met the following criteria: (1) a functional analysis of problem behavior identified two social functions (i.e., escape from demands, accesses to tangible items, and/or access to adult attention), and (2) DRA-based interventions for both functions were conducted separately. For all three cases, we determined that the obtained rates of reinforcement differed across the relevant social-function conditions of the functional analysis, with one condition producing a greater rate of reinforcement than the other (see Figure 18.1 for outcomes of functional analysis). For two of the three cases, as shown in Figure 18.2, greater resistance to



**FIGURE 18.1.** Instances of problem behavior per minute across functional analysis sessions.



**FIGURE 18.2.** Proportion of baseline rates of problem behavior across sessions of DRA treatment (left panels) and averaged across sessions of treatment (right panels).

change of problem behavior was noted in the intervention associated with the functional-analysis condition that produced the higher rate of reinforcement. These data again align with findings from basic and translational evaluations of resistance to change in that higher-rate reinforcement tended to produce more persistent behavior than did lower-rate reinforcement. From a practical standpoint, these data also suggest that preintervention assessments that include delivery of reinforcement for problem behavior can impact the initial treatment success of DRA-based interventions.

The studies and clinical demonstrations described in this section highlight the impact that parameters within an individual’s reinforcement history, such as reinforcer rate and magnitude, have on resistance to change in applied contexts. Yet these variables do not comprise a comprehensive list of factors that impact resistance to change. For example, the response selected as the alternative behavior has been demonstrated to impact resistance to change. When given the opportunity to earn reinforcement by engaging in different behaviors, individuals often demonstrate preference for one response over another

independently of the programmed reinforcement contingencies for those responses. Ringdahl et al. (2016) for example, intervened on the problem behavior of 18 individuals diagnosed with IDD using FCT. During treatment, participants were trained to emit two communication responses (e.g., activating a microswitch and manually signing) to produce functional reinforcers. When participants subsequently were given the opportunity to perform either response for reinforcement under a concurrent fixed-ratio (FR) 1/FR 1 schedule, each participant demonstrated a preference for one response over the other; that is, despite the fact that both responses produced the same consequence according to the same reinforcement schedules, participants chose to emit one response more frequently than the other. This finding replicated earlier studies by Winborn et al. (2009) and Falcomata et al. (2010) showing that not only could FCT be effective across multiple communication topographies, but also that individuals often demonstrate a preference for which topography to use when both produce equal reinforcement.

In an extension of this line of research, Ringdahl et al. (2018) evaluated whether demonstrated preference for communication topography impacted resistance to change. Similar to Falcomata et al. (2009), Ringdahl et al. (2016), and Winborn et al. (2009), participants in the Ringdahl et al. (2018) study were individuals diagnosed with IDD whose problem behavior was treated using FCT. Moreover, the FCT treatment incorporated two different communicative responses. These responses were reinforced in the context of a two-component multiple schedule. The components were signaled by differently colored poster boards. One component was associated with reinforcement for one form of communication, and the other component was associated with reinforcement for the other form of communication. Once the responses had been established in the participants' repertoires, a concurrent-schedule evaluation was conducted to identify which response was preferred. All eight participants demonstrated a preference for one of the two communicative responses. The multiple schedule was then reintroduced until rates of communication in the two components were stable, after which resistance to change of communication was assessed by introducing extinction for communication in both components. For seven of eight participants, the preferred communication response during the concurrent-schedule assessment was also the response that demonstrated the most resistance to change during the extinction assessment.

Ringdahl et al.'s (2018) findings are noteworthy, as they provided an illustration that dimensions of the *response* can play a role in determining resistance to change, whereas previous studies have, for the most part, focused exclusively on the role that dimensions of reinforcement play in determining resistance to change. One could reasonably argue, however, that response-related variables that contribute to preference do so because, much like reinforcers that are arranged purposely by experimenters or clinicians, those variables might have reinforcing properties in and of themselves. For example, pushing a microswitch may produce pleasurable sensory consequences (e.g., a satisfying "click" or other tactile stimulation) that are not produced by touching a card. Even if those sensory consequences are insufficiently reinforcing to motivate behavior in the absence of any additional, experimentally arranged reinforcement contingencies, it is conceivable that they might contribute to the value of a response. Other variables may differ between topographically different responses that may further contribute to differences in the subjective value of those responses (e.g., differences in extraexperimental reinforcement histories, response efforts). Consistent with the broader literatures on choice and resistance to change, then, one would expect the more valued response to be preferred over and more persistent than the less valued response (Grace & Nevin, 1997).

## A Conceptual Analysis: Behavioral Momentum Theory

In the preceding sections, we have described a handful of variables that reliably impact resistance to change of operant behavior, including, but not limited to, reinforcer rate, magnitude, immediacy, and quality. Moreover, we have reviewed studies that evaluated the effects of these variables across diverse species and populations engaging in myriad different behaviors of focus. Time and time again, the data have suggested that more valuable sources of reinforcement produce behavior that is more persistent than less valuable sources of reinforcement. When a general relation between an independent and dependent variable is identified, a natural next step in the scientific process is to ask, “Why are these variables related?” Nevin et al. (1983) developed “behavioral momentum theory” as a means of answering exactly this question as it relates to reinforcement effects on resistance to change.

Behavioral momentum theory (BMT) draws parallels between the way that an operant behavior resists changes in its rate when that behavior is faced with disruption and the way that a moving object resists changes in its velocity when a force that opposes motion acts on that object. Imagine gently rolling a ping-pong ball across a dinner table toward a desk fan. The breeze from the fan will oppose the ping-pong ball’s motion. After a few seconds, and before it reaches the fan, the ping-pong ball will likely stop rolling and probably start rolling back toward you. Try recreating that situation with a bowling ball, and you are likely to need a new desk fan!<sup>2</sup> That is, the bowling ball may slow down slightly as it rolls across the table, but the breeze generated by the desk fan is likely to be insufficient to stop the ball’s motion before it collides with the fan. As this example illustrates, the larger an object’s mass, the more it resists changes in its velocity. Nevin et al. (1983) argued that delivering reinforcers in the presence of a discriminative stimulus produces a Pavlovian (stimulus–stimulus) association between the reinforcers and the stimulus in the presence of which they are delivered. According to BMT, this Pavlovian stimulus–reinforcer relation imparts a mass-like quality to behavior that causes it to persist when disrupted. Reinforcers of higher value produce stronger Pavlovian relations than do reinforcers of lower value, thereby producing more “behavioral mass” and greater resistance to change. Recall the Nevin et al. (1990) and Mace et al. (1990) findings described earlier. These studies have been used as principal support for the notion that *Pavlovian* contingencies instead of *operant* contingencies govern resistance to change.

Since its development 40 years ago, BMT has shaped the way behavior analysts think about resistance to change as we have defined it for the purpose of this chapter (resistance to change in the face of extinction, reinforcer satiation, distraction, etc.). It has strongly influenced research on other topics, too, including relapse (see, e.g., Saini et al., Chapter 19, this volume), attentional (e.g., Nevin et al., 2005; Podlesnik, Thrailkill, et al., 2012), and memorial processes (e.g., Nevin et al., 2003, 2008; Odum et al., 2005). Importantly, for our present purposes, BMT has served as a catalyst for myriad translational and applied work aimed at increasing the efficiency and long-term efficacy of behavioral interventions. By way of example, recall the Mace et al. (2010) findings described earlier: Participants’ problem behavior tended to be more resistant to change following relatively high-quality DRA reinforcement than following relatively low-quality reinforcement for problem behavior. From the perspective of BMT, this outcome was observed because DRA reinforcers contributed to the Pavlovian stimulus–reinforcer relation in the

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<sup>2</sup>Readers, do not try this thought experiment at home. The authors of this chapter take no responsibility for incidents involving desk fans or bowling balls that may ensue.

treatment situation, thus enhancing the behavioral mass and resistance to change of the participants' problem behavior *even though those reinforcers were delivered contingently on a different behavior* (for further discussion, see Craig & Shahan, 2016a; Nevin et al., 2017; Nevin & Shahan, 2011; Shahan & Sweeney, 2011).

Armed with the insights from BMT about *why* DRA might have increased resistance to extinction of participants' problem behavior, Mace et al. (2010) set out to develop a solution to this problem in the basic laboratory (their Experiment 2) and evaluated the viability of this solution in the context of clinically significant problem behavior (their Experiment 3). These experiments were complicated, but their rationale was simple: If an alternative response is established and frequently reinforced in a stimulus context that is different from the context previously associated with reinforcement for problem behavior, those reinforcers should not contribute to the mass, or increase resistance to change, of problem behavior. The procedures used in these experiments were very similar, so we focus specifically on the outcomes from their Experiment 3. Participants were two males who engaged in severe problem behavior. During baseline, three different conditions were arranged across sessions, each of which was associated with different discriminative stimuli (i.e., rooms, therapists' gown colors). In Condition 1, therapists delivered a relatively low rate of reinforcement (48 reinforcers per hour) for problem behavior. In Condition 2, problem behavior produced the same low rate of reinforcement as it had in Condition 1, but an additional 180 reinforcers per hour were available for appropriate requests. Finally, in Condition 3, appropriate requests produced as many as 180 reinforcers per hour, but problem behavior was placed on extinction.

Mace et al. (2010) assessed how the different reinforcement conditions just described affected resistance to change of problem behavior in a follow-up extinction test. Here, participants experienced extinction for problem behavior and appropriate communication in three stimulus situations: The situation previously associated with Condition 1 (reinforcement for problem behavior only during baseline), the situation previously associated with Condition 2 (reinforcement for problem behavior and appropriate requests at the same time during baseline), and a new situation that included a combination of stimuli from Conditions 1 (reinforcement for problem behavior only during baseline) and 3 (reinforcement for appropriate requests only during baseline). They found that participants' problem behavior persisted to the greatest degree in the stimulus situation associated with concurrent reinforcement of problem and alternative behavior during baseline (i.e., Condition 2). Moreover, resistance to change of problem behavior was relatively low and about the same in the tests that included only Condition-1 stimuli and Condition-1 + Condition-3 stimuli. Thus, consistent with the predictions of BMT and the authors' hypothesis, delivering reinforcers for alternative behavior in a stimulus context that was separate from the context in which problem behavior previously was reinforced appeared to prevent those reinforcers from contributing to the resistance to change of problem behavior (for similar findings, see Craig et al., 2018; Podlesnik, Bai, et al., 2012). These findings underscore not only the utility of BMT (and other quantitative theories of behavior) for practice but also, as we alluded to previously, the utility of translational research methods for overcoming barriers to treatment in real-world situations.

In addition to the Mace et al. (2010) findings, there are many other examples of translational applications of BMT to inform clinical interventions. Providing a review, or even a semiexhaustive bibliography, of this work is outside the scope of this chapter (for interested readers, see Fisher et al., 2019; Mace & Nevin, 2017; Podlesnik & DeLeon, 2015). Nevertheless, and despite the wealth of data that provide support for BMT and

its implications for research and practice, it is by no means without its limitations. The shortcomings of the theory have been exhaustively reviewed by others (e.g., Craig et al., 2014; Nevin et al., 2017; Shahan & Craig, 2017). We provide a brief overview of two of these problems, however, because they call into question the basic arguments that BMT puts forward. Moreover, when evaluating a way of thinking about a behavior process, it is important to critically analyze all dimensions of the argument put forward: the good, the bad, and the ugly.

As we described earlier when reviewing Nevin (1974), when extinction is applied as a disruptor, higher rates of reinforcement produce greater resistance to change than do lower rates when the different reinforcement conditions are arranged within the components of a multiple schedule. When different reinforcement rates are arranged in single schedules of reinforcement, higher rates tend to produce behavior that is *less* resistant to extinction than lower rates (see Craig & Shahan, 2016a, 2016b, 2018; Shull & Grimes, 2006). Cohen (1998), for example, evaluated the effects of reinforcer rates on resistance to extinction of rats' lever pressing in a series of conditions. In the "Multiple" condition, rats experienced both high- (VI 30 second) and low-rate (VI 120 second) reinforcement for lever pressing within sessions in the components of a multiple schedule. The components of the multiple schedule were signaled by presentation of a steady or blinking house light inside the operant chamber. In the "Alternating" condition, the rate of reinforcement for lever pressing alternated between high and low across successive sessions, and the "Successive" condition arranged protracted phases in which rats experienced only high or low reinforcer rates. In these two conditions, the different reinforcer rates were correlated with either a steady or flashing house light as in the Multiple condition. Thus, the only difference between these three conditions was how often the high- and low-rate reinforcement schedules (and their correlated stimuli) alternated. Resistance to change of lever pressing in the face of extinction was assessed in the Multiple and Alternating conditions by continuing the conditions without reinforcement. In the Successive condition, individual extinction tests followed each reinforcer-rate phase.

As one would predict based on BMT, Cohen (1998) found that lever pressing was more resistant to change in the stimulus situation that was associated with the high rate of reinforcement than in the situation associated with the low rate of reinforcement in the Multiple and Alternating conditions. This prediction did not, however, bear out in the Successive condition. Here, lever pressing was *less* resistant to extinction in the high-rate than in the low-rate stimulus situation. It is unclear why reinforcer rates and the stimulus–reinforcer relations they produce would affect extinction performance differently in these conditions (i.e., enhancing resistance to change in multiple schedules and deterring resistance in single schedules). Thus, these and other, similar findings call into question the generality of the description of resistance to change offered by BMT.<sup>3</sup>

A second complication for BMT relates to the assertion of the theory that response rates and resistance to change are governed by different contingencies (operant response–reinforcer and Pavlovian stimulus–reinforcer contingencies, respectively). If this were

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<sup>3</sup>Others (e.g., Nevin & Grace, 2005; Shull & Grimes, 2006) have presented methods for using the quantitative framework offered by BMT to account for differences in reinforcer–rate effects on resistance to change during extinction between single and multiple schedules. It is important to note, however, that these approaches entail large and otherwise unexplained variation in model parameters between single and multiple schedules (for discussion, see Craig & Shahan, 2016b). Inasmuch, these approaches offer up as many questions about BMT's description of extinction performance as they claim to solve.

true, the rate at which behavior occurs before it is disrupted should have no impact on how resistant to change it is during disruption. This basic assertion of BMT is not always supported.

Nevin et al. (2001, Experiment 1), for example, trained pigeons to peck keys for food reinforcers in a two-component multiple schedule. One component arranged reinforcement for pecking according to a variable-ratio (VR) 60 schedule, and the other arranged reinforcement according to a VI schedule. The mean value of the VI was titrated across sessions for each pigeon until the rates of reinforcement delivered by the VR and VI schedules were equivalent. Consistent with previous reports (Baum, 1993; Zuriff, 1970), the VR schedule produced higher rates of key pecking than did the VI schedule. When pecking subsequently was disrupted by either extinction or partial reinforcer satiation, responding in the VI component tended to be more resistant to change than responding in the VR component. All else being equal, behavior that occurs at a low rate predisruption tends to persist to a greater degree than behavior that occurs at a high rate predisruption. Moreover, this finding appears to be robust and has been demonstrated when response-rate differentials are produced by different reinforcement schedules (e.g., Nevin et al., 2001), pacing schedules (Lattal, 1989), or even naturally occurring variability in response rate (Kuroda et al., 2018).

These and other complications for BMT have led some, including ourselves, to argue that the underlying processes evoked by BMT need no longer be considered serious candidate processes to explain resistance to change (see Bell & Baum, 2021; Craig, in press; Nevin et al., 2017; Shahan & Craig, 2017). Nevertheless, it is important to acknowledge that the predictions of BMT, though sometimes imprecise or even flat-out contradicted by empirical outcomes, are often supported. Thus, BMT may, at the least, provide a useful heuristic for identifying experimental and treatment variables that may affect resistance to change.

### **Clinical Implications of Basic, Translational, Applied, and Conceptual Analyses of Resistance to Change**

Research related to resistance to change and the relevant variables impacting it began in basic investigations (e.g., Nevin, 1974) and progressed to translational demonstrations (e.g., Mace, 1990; McComas, 2008) and application (e.g., Ringdahl et al., 2018; Wacker et al., 2011). Currently, much of the research on the topic occurs in the context of assessment and intervention related to socially significant clinical concerns such as communication delays and severe problem behavior. For example, both the Ringdahl et al. (2018) and Wacker et al. (2011) studies evaluated resistance to change in the context of intervention for severe problem behavior exhibited by individuals with IDD in which appropriate, alternative responses (i.e., communication) were reinforced, while problem behavior was placed on extinction. Prevalence estimates of severe problem behavior range from 10 to 15% in the population of individuals with IDD (Emerson et al., 2001), and problem behaviors within this population often are communicative in nature (Beavers et al., 2013). Thus, demonstrating how the resistance to change of communicative behavior (Wacker et al., 2011) changes over time and evaluating variables that impact resistance to change of communicative behavior (Ringdahl et al., 2018) represent examples of research that is designed to translate what has been shown in the basic behavioral literature toward the improvement and refinement of interventions conducted in applied contexts.



The current trend of research related to the resistance to change of socially significant behavior highlights the utility of understanding the relations between reinforcement history and resistance to change when developing impactful interventions. Ultimately, any behavior change program has the goal of being durable and affecting lasting behavior change that does not wane immediately upon discontinuation of supporting contingencies. The existing applied literature demonstrates that what is done prior to and during intervention alters resistance to change.

Specifically, the findings of Lerman et al. (1996), MacDonald et al. (2013), and the unpublished clinical data from the University of Georgia reviewed earlier demonstrate that practitioners should be aware of the relative frequency of reinforcement before intervention is implemented, so that they can prepare care providers regarding the likely course of treatment. For example, if problem behavior resulted in a relatively high rate of reinforcement, caregivers could be counseled that intervention may be slow to have the desired impact given the relation between high rates of reinforcement and increased resistance to change. Similarly, these findings suggest that programming relatively lean reinforcement schedules during preintervention baselines may enhance initial intervention effects. Collectively, these demonstrations highlight the potential importance of considering reinforcement history prior to implementing intervention and how reinforcers are programmed during intervention to support alternative, appropriate behavior.

The findings reported by Romani et al. (2016) suggest that reinforcement history during intervention impacts the resistance to change of appropriate, alternative behavior reinforced to replace problem behavior. Specifically, higher rates of reinforcement received during intervention may result in enhanced resistance to change of the replacement behavior. These treatment variables may allow treatment effects to be resilient in the face of challenges such as brief exposures to extinction that might happen when someone unfamiliar with a behavior plan is providing care to the individual.

Finally, data reported by Ringdahl et al. (2018) demonstrated that, in addition to reinforcement variables such as rate, magnitude, quality, or immediacy, response-specific variables may play a role in determining resistance to change. Specifically, to increase the resistance to change of appropriate behavior introduced into a repertoire, practitioners may want to take the additional step of determining whether a preference exists among candidate alternative responses. As currently implemented, many DRA- and FCT-based interventions include selection of alternative responses based on practical or experiential variables. For example, use of a tablet-based augmentative and alternative communication system may be pursued in the context of FCT, because a classroom teacher has access to tablets and the school district owns a subscription to the communication system. In another instance, picture exchange may be selected as the alternative response, because the individual has had previous experience with this communication system and the implementer is familiar with its procedures based on their experience with other students or clients. While these variables may be important to consider, they have not been demonstrated to impact resistance to change, and future research on this topic is warranted.

The conceptual analysis of resistance to change offered by BMT provides additional insights into resistance to change that may be practically useful. Behavioral theories in general are helpful for a number of reasons: (1) They help us to organize the way that we think about behavioral outcomes and functional relations, (2) they allow us to make sense of broad and often complicated bodies of literature using a few key assumptions, and (3) they enable researchers and practitioners to make precise predictions about the effects of an independent variable on a dependent variable. To these ends, we introduced

BMT in the preceding section for several reasons. First, it has played an important role in guiding basic, translational, and applied research on resistance to change. Second, it offers a reasonably straightforward metaphor for understanding why and how variables such as reinforcer rate, magnitude, quality, and immediacy impact resistance to change. We should also note that various quantitative models of resistance to change have been based on the argument put forward by BMT (see Nevin et al., 2017; Nevin & Grace, 2000; Nevin & Shahan, 2011). If practitioners know the specific parameters of reinforcement they plan to arrange during a treatment evaluation, they may use these models to generate predicted behavior during treatment on a session-by-session basis.

We have provided an overview of some of the challenges to the BMT because, just as it is important to understand the potential utility of behavioral theories for practice, it is important to appreciate that BMT is wrong. Earlier, we provided some examples of why BMT is wrong (e.g., the relation between preextinction reinforcer rates and resistance to extinction in single schedules of reinforcement opposes BMT's predictions, response rate and resistance to change appear to be related when the theory suggests that no such relation should exist), but these are not the only reasons to question the theory's assertions (see Craig et al., in press; Nevin et al., 2017). In saying that the theory is wrong, however, we do not mean that it is not useful. To demonstrate this point by way of analogy, consider for a moment the classical mechanics on which BMT is based. Despite its shortcomings, classical mechanics played a critical role in establishing our current understanding of how the physical world works. Only by identifying shortcomings of these basic tenets were researchers and theoreticians able to develop more general physical principles such as quantum mechanics. Likewise, BMT has played a critical role in leading researchers to discover variables that affect resistance to change of operant behavior. Identifying higher-order dependent variables that affect resistance to change could continue to shape our understanding of resistance-to-change mechanisms and operant behavior more generally.

## Conclusions

Resistance to change is an important dimension of operant behavior that is directly relevant to clinical applications of behavior analysis. Basic, translational, and conceptual analyses of resistance to change point toward simple manipulations that are likely to make behavior more or less persistent. On the one hand, resistance to change of desirable behavior may be promoted by arranging higher rate, larger magnitude, better quality, or more immediate reinforcers. On the other hand, resistance to change of undesirable behavior may be deterred by arranging lower rate, smaller magnitude, worse quality, or more delayed reinforcers. Many of these functional relations have borne out in real-world situations with clinical populations and socially relevant behaviors.

Moreover, the study of resistance to change highlights the utility of bidirectional translational research in behavior analysis. In the traditional progression of translational research, findings from the bench are translated to the bedside; that is, basic research leads to the discovery of principles and development of technologies that are helpful when translated into application. As we have demonstrated in this chapter, some resistance-to-change research has followed this progression. It has also, however, placed emphasis on reverse translation: moving the analysis of real-world problems into the basic and translational laboratories (e.g., Craig et al., 2018; Mace et al., 2010; Nevin et al., 2016; Sweeney

et al., 2014). As this literature demonstrates, the process of cyclical learning (Kasichay-anula & Vankatakrishnan, 2018), of moving from bench to bedside and back again, can help us understand why barriers to treatment exist and how we can overcome them. We encourage readers to embrace this approach to behavior-analytic research.

## REFERENCES

- Bai, J. Y. H., & Podlesnik, C. A. (2017). No impact of repeated extinction exposures on operant responding maintained by different reinforcement rates. *Behavioural Processes, 138*, 29–33.
- Baum, W. M. (1974). On two types of deviation from the matching law: Bias and undermatching. *Journal of the Experimental Analysis of Behavior, 22*, 231–242.
- Baum, W. M. (1993). Performances on ratio and interval schedules of reinforcement: Data and theory. *Journal of the Experimental Analysis of Behavior, 59*, 245–264.
- Baum, W. M., & Rachlin, H. C. (1969). Choice as time allocation. *Journal of the Experimental Analysis of Behavior, 12*, 861–874.
- Beavers, G. A., Iwata, B. A., & Lerman, D. C. (2013). Thirty years of research on the functional analysis of problem behavior. *Journal of Applied Behavior Analysis, 46*, 1–21.
- Bell, M. C. (1999). Pavlovian contingencies and resistance to change in a multiple schedule. *Journal of the Experimental Analysis of Behavior, 72*, 81–96.
- Bell, M. C., & Baum, W. M. (2021). Resistance to extinction versus extinction as discrimination. *Journal of the Experimental Analysis of Behavior, 115*, 702–716.
- Blackman, D. E. (1968). Response rate, reinforcement frequency, and conditioned suppression. *Journal of the Experimental Analysis of Behavior, 11*, 503–516.
- Carr, E. G., & Durand, V. M. (1985). Reducing behavior problems through functional communication training. *Journal of Applied Behavior Analysis, 18*(2), 111–126.
- Cohen, S. L. (1998). Behavioral momentum: The effects of the temporal separation of rates of reinforcement. *Journal of the Experimental Analysis of Behavior, 69*, 29–47.
- Cohen, S. L., Riley, D. S., & Weigle, P. A. (1993). Tests of behavioral momentum in simple and multiple schedules with rats and pigeons. *Journal of the Experimental Analysis of Behavior, 60*, 255–291.
- Craig, A. R. (in press). Resistance to change of behavior and theory. *Journal of the Experimental Analysis of Behavior*. [Epub ahead of print]
- Craig, A. R., Cunningham, P. J., & Shahan, T. A. (2015). Behavioral momentum and accumulation of bass in multiple schedules. *Journal of the Experimental Analysis of Behavior, 103*, 437–449.
- Craig, A. R., Cunningham, P. J., Sweeney, M. M., Shahan, T. A., & Nevin, J. A. (2018). Delivering alternative reinforcement in a distinct context reduces its counter-therapeutic effects on relapse. *Journal of the Experimental Analysis of Behavior, 109*, 492–505.
- Craig, A. R., Nevin, J. A., & Odum, A. L. (2014). Behavioral momentum and resistance to change. In F. K. McSweeney & E. S. Murphy (Eds.), *The Wiley Blackwell handbook of operant and classical conditioning* (pp. 249–274). Wiley Blackwell.
- Craig, A. R., & Shahan, T. A. (2016a). Behavioral momentum theory fails to account for the effects of reinforcement rate on resurgence. *Journal of the Experimental Analysis of Behavior, 105*, 375–392.
- Craig, A. R., & Shahan, T. A. (2016b). Experience with dynamic reinforcement rates decreases resistance to extinction. *Journal of the Experimental Analysis of Behavior, 105*, 291–306.
- Craig, A. R., & Shahan, T. A. (2018). Multiple schedules, off-baseline reinforcement shifts, and resistance to extinction. *Journal of the Experimental Analysis of Behavior, 109*, 148–163.
- Craig, A. R., & Shahan, T. A. (2022). Non-drug reinforcers contingent on alternative behavior or abstinence increase resistance to extinction and reinstatement of ethanol-maintained behavior. *Journal of the Experimental Analysis of Behavior, 118*, 353–375.
- Craig, A. R., Sweeney, M. M., & Shahan, T. A. (2019). Behavioral momentum and resistance to extinction across repeated extinction tests.

- Journal of the Experimental Analysis of Behavior*, 112, 290–309.
- Emerson, E., Kiernan, C., Alborz, A., Reeves, D., Mason, H., Swarbrick, R., . . . Hatton, C. (2001). The prevalence of challenging behaviors: A total population study. *Research in Developmental Disabilities*, 22, 77–93.
- Falcomata, T. S., Ringdahl, J. E., Christensen, T. J., & Boelter, E. W. (2010). An evaluation of prompt schedules and mand preference during functional communication training. *The Behavior Analyst Today*, 11, 77–84.
- Fisher, W. W., Greer, B. D., Craig, A. R., Retzlaff, B. J., Fuhrman, A. M., & Lichtblau, K. R. (2019). On the predictive validity of behavioral momentum theory for mitigating resurgence of problem behavior. *Journal of the Experimental Analysis of Behavior*, 109, 281–290.
- Fleming, A. (1929). On the antibacterial action of cultures of a Penicillium, with special reference to their use in the isolation of B. influenzae. *British Journal of Experimental Pathology*, 10, 226–236.
- Gallistel, C. R. (2012). Extinction from a rationalist perspective. *Behavioral Processes*, 90, 66–80.
- Grace, R. C., & Nevin, J. A. (1997). On the relation between preference and resistance to change. *Journal of the Experimental Analysis of Behavior*, 67, 43–65.
- Grimes, J. A., & Shull, R. L. (2001). Response-independent milk delivery enhances persistence of pellet-reinforced lever pressing by rats. *Journal of the Experimental Analysis of Behavior*, 76, 179–194.
- Harper, D. N., & McLean, A. P. (1992). Resistance to change and the law of effect. *Journal of the Experimental Analysis of Behavior*, 57, 317–337.
- Herrnstein, R. J. (1961). Relative and absolute strength of response as a function of frequency of reinforcement. *Journal of the Experimental Analysis of Behavior*, 4, 267–272.
- Herrnstein, R. J. (1970). On the law of effect. *Journal of the Experimental Analysis of Behavior*, 13, 243–266.
- Igaki, T., & Sakagami, T. (2004). Resistance to change in goldfish. *Behavioural Processes*, 66, 139–152.
- Iwata, B. A., Dorsey, M. F., Slifer, K. J., Bauman, K. E., & Richman, G. S. (1994). Toward a functional analysis of self-injury. *Journal of Applied Behavior Analysis*, 27, 197–209.
- Kasichayanula, S., & Venkatakrisnan, K. (2018). Reverse translation: The art of cyclical learning. *Clinical Pharmacology and Therapeutics*, 103, 152–159.
- Kuroda, T., Cook, J. E., & Lattal, K. A. (2018). Baseline response rates affect resistance to change. *Journal of the Experimental Analysis of Behavior*, 109, 164–175.
- Lattal, K. A. (1989). Contingencies on response rate and resistance to change. *Learning and Motivation*, 20, 191–203.
- Lerman, D. C., Iwata, B. A., Shore, B. A., & Kahng, S. (1996). Responding maintained by intermittent reinforcement: Implications for the use of extinction with problem behavior in clinical settings. *Journal of Applied Behavior Analysis*, 29, 153–171.
- Leon, Y., Borrero, J. C., & DeLeon, I. G. (2016). Parametric analysis of delayed primary and conditioned reinforcers. *Journal of Applied Behavior Analysis*, 49, 639–655.
- MacDonald, J. M., Ahearn, W. H., Parry-Cruwys, D., & Bancroft, S. (2013). Persistence during extinction: Examining the effects of continuous and intermittent reinforcement on problem behavior. *Journal of Applied Behavior Analysis*, 46, 333–338.
- Mace, F. C., & Critchfield, T. S. (2010). Translational research in behavior analysis: Historical traditions and imperative for the future. *Journal of the Experimental Analysis of Behavior*, 93, 293–312.
- Mace, F. C., Lalli, J. S., Shea, M. C., Lalli, E. P., West, B. J., Roberts, M., & Nevin, J. A. (1990). The momentum of human behavior in a natural setting. *Journal of the Experimental Analysis of Behavior*, 54, 163–172.
- Mace, F. C., Mauro, B. C., Boyajian, A. E., & Eckert, T. L. (1997). Effects of reinforcer quality on behavioral momentum: Coordinated applied and basic research. *Journal of Applied Behavior Analysis*, 30, 1–20.
- Mace, F. C., McComas, J. J., Mauro, B. C., Progar, P. R., Taylor, B., Ervin, R., & Zangrillo, A. N. (2010). Differential reinforcement of alternative behavior increases resistance to extinction: Clinical demonstration, animal modeling, and clinical test of one solution. *Journal of the Experimental Analysis of Behavior*, 93, 349–367.
- Mace, F. C., & Nevin, J. A. (2017). Maintenance, generalization, and treatment relapse: A behavioral momentum analysis. *Education and Treatment of Children*, 40, 27–42.

- McComas, J. J., Hartman, E. C., & Jimenez, A. (2008). Some effects of magnitude of reinforcement on persistence of responding. *The Psychological Record*, *58*(4), 517–528.
- McIlvane, W. J. (2009). Translational behavior analysis: From laboratory science in stimulus control to intervention with persons with neurodevelopmental disabilities. *Behavior Analyst*, *32*, 273–280.
- Nall, R. W., Craig, A. R., Browning, K. O., & Shahan, T. A. (2018). Longer treatment with alternative non-drug reinforcement fails to reduce resurgence of cocaine or alcohol seeking in rats. *Behavioral Brain Research*, *341*, 54–62.
- Nevin, J. A. (1974). Response strength in multiple schedules. *Journal of the Experimental Analysis of Behavior*, *21*, 389–408.
- Nevin, J. A. (1992). An integrative model for the study of behavioral momentum. *Journal of the Experimental Analysis of Behavior*, *57*, 301–316.
- Nevin, J. A., Craig, A. R., Cunningham, P. J., Podlesnik, C. A., Shahan, T. A., & Sweeney, M. M. (2017). Quantitative models of persistence and relapse from the perspective of behavioral momentum theory: Fits and misfits. *Behavioural Processes*, *141*, 92–99.
- Nevin, J. A., Davison, M., & Shahan, T. A. (2005). A theory of attending and reinforcement in conditional discriminations. *Journal of the Experimental Analysis of Behavior*, *84*, 281–303.
- Nevin, J. A., & Grace, R. C. (2000). Behavioral momentum and the Law of Effect. *Behavioral and Brain Sciences*, *23*(1), 73–130.
- Nevin, J. A., & Grace, R. C. (2005). Resistance to extinction in the steady state and in transition. *Journal of Experimental Psychology: Animal Behavior Processes*, *31*, 199–212.
- Nevin, J. A., Grace, R. C., Holland, S., & McLean, A. P. (2001). Variable-ratio versus variable-interval schedules: Response rate, resistance to change, and preference. *Journal of the Experimental Analysis of Behavior*, *76*, 43–74.
- Nevin, J. A., Mace, F. C., DeLeon, I. G., Shahan, T. A., Shamlian, K. D., Lit, K., . . . Craig, A. R. (2016). Effects of signaled and unsignaled alternative reinforcement on persistence and relapse in children and pigeons. *Journal of the Experimental Analysis of Behavior*, *106*, 34–57.
- Nevin, J. A., Mandell, C., & Atak, J. R. (1983). The analysis of behavioral momentum. *Journal of the Experimental Analysis of Behavior*, *39*, 49–59.
- Nevin, J. A., Milo, J., Odum, A. L., & Shahan, T. A. (2003). Accuracy of discrimination, rate of responding, and resistance to change. *Journal of the Experimental Analysis of Behavior*, *79*, 307–321.
- Nevin, J. A., & Shahan, T. A. (2011). Behavioral momentum theory: Equations and applications. *Journal of Applied Behavior Analysis*, *44*, 877–895.
- Nevin, J. A., Shahan, T. A., & Odum, A. L. (2008). Contrast effects in response rate and accuracy of delayed matching to sample. *Quarterly Journal of Experimental Psychology*, *61*, 1400–1409.
- Nevin, J. A., Tota, M. E., Torquato, R. D., & Shull, R. L. (1990). Alternative reinforcement increases resistance to change: Pavlovian or operant contingencies? *Journal of the Experimental Analysis of Behavior*, *53*, 359–379.
- Odum, A. L., Shahan, T. A., & Nevin, J. A. (2005). Resistance to change of forgetting functions and response rates. *Journal of the Experimental Analysis of Behavior*, *84*, 65–75.
- Podlesnik, C. A., Bai, J. Y. H., & Elliffe, D. (2012). Resistance to extinction and relapse in combined stimulus contexts. *Journal of the Experimental Analysis of Behavior*, *98*, 169–189.
- Podlesnik, C. A., & DeLeon, I. G. (2015). Behavioral momentum theory: Understanding persistence and improving treatment. In F. D. D. Reed & D. D. Reed (Eds.), *Autism and child psychopathology series. Autism service delivery: Bridging the gap between science and practice* (pp. 327–351). Springer Science + Business Media.
- Podlesnik, C. A., Jimenez-Gomez, C., Ward, R. D., & Shahan, T. A. (2006). Resistance to change of responding maintained by unsignaled delays to reinforcement: A response-out analysis. *Journal of the Experimental Analysis of Behavior*, *85*, 329–347.
- Podlesnik, C. A., & Shahan, T. A. (2009). Behavioral momentum and relapse of extinguished operant responding. *Learning and Behavior*, *37*, 357–364.
- Podlesnik, C. A., Thrailkill, E., & Shahan, T. A. (2012). Differential reinforcement and resistance to change of divided-attention performance. *Learning and Behavior*, *40*, 158–169.
- Pyszczynski, A. D., & Shahan, T. A. (2011). Behavioral momentum and relapse of ethanol

- seeking: Nondrug reinforcement in a context increases relative reinstatement. *Behavioural Pharmacology*, 22, 81–86.
- Rau, J. C., Pickering, L. D., & McLean, A. P. (1996). Resistance to change as a function of concurrent reinforcer magnitude. *Behavioural Processes*, 38, 253–264.
- Ringdahl, J. E., Berg, W. K., Wacker, D. P., Ryan, S., Ryan, A., Crook, K., & Molony, M. (2016). Further demonstrations of individual preference among mand modalities during functional communication training. *Journal of Developmental and Physical Disabilities*, 28, 905–917.
- Ringdahl, J. E., Crook, K., Molony, M. A., Zabala, K., Taylor, C. J., Berg, W. K., . . . Neurnberger, J. E. (2018). Effects of response preference on resistance to change. *Journal of the Experimental Analysis of Behavior*, 109, 265–280.
- Romani, P. W., Ringdahl, J. E., Wacker, D. P., Lustig, N. H., Vinquist, K. M., Northup, J., . . . Carrion, D. P. (2016). Relations between rate of negative reinforcement and the persistence of task completion. *Journal of Applied Behavior Analysis*, 49, 122–137.
- Shahan, T. A., Browning, K. O., & Nall, R. W. (2020). Resurgence as choice in context: Treatment duration and on/off alternative reinforcement. *Journal of the Experimental Analysis of Behavior*, 113, 57–76.
- Shahan, T. A., & Burke, K. A. (2004). Ethanol-maintained responding of rats is more resistant to change in a context with added non-drug reinforcement. *Behavioural Pharmacology*, 15, 279–285.
- Shahan, T. A., & Craig, A. R. (2017). Resurgence as choice. *Behavioural Processes*, 141, 100–127.
- Shahan, T. A., & Sweeney, M. M. (2011). A model of resurgence based on behavioral momentum theory. *Journal of the Experimental Analysis of Behavior*, 95, 91–108.
- Shull, R. L., & Grimes, J. A. (2006). Resistance to extinction following variable-interval reinforcement: Reinforcer rate and amount. *Journal of the Experimental Analysis of Behavior*, 85, 23–39.
- Skinner, B. F. (1956). A case history in scientific method. In B. F. Skinner (Ed.), *Cumulative record* (pp. 76–100). Appleton-Century-Crofts.
- Skinner, B. F. (1979). *The shaping of a behaviorist: Part two of an autobiography*. Knopf.
- Sweeney, M. M., Moore, K., Shahan, T. A., Ahearn, W. H., Dube, W. V., & Nevin, J. A. (2014). Modeling the effects of sensory reinforcers on behavioral persistence with alternative reinforcement. *Journal of the Experimental Analysis of Behavior*, 102, 252–266.
- Tan, S. Y., & Tatsumura, Y. (2015). Alexander Fleming (1881–1955): Discoverer of penicillin. *Singapore Medical Journal*, 56, 366–367.
- Vargo, K. K., & Ringdahl, J. E. (2015). An evaluation of resistance to change with unconditioned and conditioned reinforcers. *Journal of Applied Behavior Analysis*, 48(3), 643–662.
- Wainwright, M., & Swan, H. T. (1986). C. G. Paine and the earliest surviving clinical records of penicillin therapy. *Medical History*, 30, 42–56.
- Wacker, D. P., Harding, J. W., Berg, W. K., Lee, J. F., Schieltz, K. M., Padilla, Y. C., . . . Shahan, T. A. (2011). An evaluation of persistence of treatment effects during long-term treatment of destructive behavior. *Journal of the Experimental Analysis of Behavior*, 96, 261–282.
- Winborn-Kemmerer, L., Ringdahl, J. E., Wacker, D. P., & Kitsukawa, K. (2009). A demonstration of individual preference for novel mands during functional communication training. *Journal of Applied Behavior Analysis*, 42, 185–189.
- Zuriff, G. E. (1970). A comparison of variable-ratio and variable-interval schedules of reinforcement. *Journal of the Experimental Analysis of Behavior*, 13, 369–374.