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Behavioral Momentum: Translational Research in Intellectual and Developmental Disabilities

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Abstract

Behavioral momentum theory (Nevin, 1992, Nevin & Grace, 2000) describes the relation between the characteristic level of reinforcement within a context and behavioral resistance to change within that context. This paper will describe the multiple-schedule-disrupter paradigm for basic behavioral momentum research and illustrate it with two representative examples from the literature with non-human subjects. The remainder of the paper will provide a review of translational research in human populations with intellectual and developmental disabilities (IDD) employing the multiple-schedule-disrupter paradigm and closely related variations. The results of this research show that the reinforcer-rate effects predicted by behavioral momentum theory are widely replicated in IDD populations. The intended audience for this paper is the practitioner interested in learning about the current status of translational research in behavioral momentum as a foundation for considering ways in which behavioral momentum theory may be relevant to clinical issues.

Keywords

behavioral momentum; behavioral persistence; resistance to change; reinforcer rate; intellectual disability

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During Nancy Neef's tenure as editor of the Journal of Applied Behavior Analysis, there was an increasing trend in the number of articles in that journal that sought to establish a connection between basic and applied research (Wacker, 1996). Wacker (1996) explicitly pointed out the “need for studies that bridge basic and applied research,” the trend continued during his term as JABA's editor, and one began to hear the term “bridge study” with increasing frequency among behavior analysts. Now, over 12 years later, the importance of translational research is almost universally acknowledged within our field (e.g., McIlvane et al., in press). Such research – occupying a conceptual midpoint between basic research and applied research – has become a priority at the highest levels of science and medicine, for example, as seen in the establishment of the National Institutes of Health new Clinical and Translational Science Award (e.g., Morrison, 2008).

The Behavior Analyst Today (BAT) was “founded as a newsletter for master level practitioners … [and] has evolved to being a primary form of communication between researchers and practitioners, as well as a primary form of communication for those outside behavior analysis" (BAT, 2004). For this reason, the intended audience for this paper is the practitioner interested in learning about the current status of translational research in behavioral momentum as a foundation for considering ways in which behavioral momentum theory may – or may not – be relevant to clinical issues. This paper will provide a selective review of that translational research, with an emphasis on human populations with intellectual and developmental disabilities (IDD). We will describe some of the ways in which momentum theory, arising in the basic research laboratory with nonhuman animals, has been shown to be applicable to the behavior of humans with IDD.

Nevin's behavioral momentum theory (Nevin, 1992, Nevin & Grace, 2000) makes an analogy between the relationships described in the physics of motion and the measurement of response strength. In classical mechanics, the momentum of a moving body is defined as the product of its velocity and mass. Nevin (1992) suggested a parallel in behavior. Rate of responding is analogous to velocity, and resistance to change analogous to mass. Resistance to change refers to the persistence of behavior in the face of some perturbing force or operation (e.g., distraction), and this behavioral analogue of mass is positively related to the overall level of reinforcement signaled by the stimuli that define the context in which the behavior occurs.

Consider a basketball and a bowling ball rolling down an inclined plane at equal speeds. Although velocities are equal, the force necessary to decelerate the bowling ball will be greater because of its greater mass; the bowling ball is more resistant to change. Now consider two operant responses, controlled by different discriminative stimuli A and B, but occurring at the same rate (velocity). According to behavioral momentum theory, if the historical level of reinforcement for the response controlled by stimulus A is greater than that for the response controlled by stimulus B, then response A will be more resistant to change than response B.

Basic Laboratory Research with Nonhuman Animals: Two Examples

We will begin by briefly describing two representative experiments from the basic research laboratory. These experiments illustrate a commonly used arrangement to study behavioral momentum, here designated as the multiple -schedule disrupter paradigm. We will use them to make three points that are important for evaluating the translational research to be discussed below: (a) In the basic research laboratory, resistance to change is assessed by relative measures; (b) given behavior in two contexts with different characteristic levels of reinforcement, behavior in the richer context will be more resistant to change; and (c) resistance to change is determined by the stimulus-reinforcer relations of the reinforcement contingencies.

Nevin (1974) established responding in food-deprived pigeons on a multiple VI 60 s VI 180 s schedule with time out periods between components. Rates of obtained reinforcers were thus approximately three times higher in one component than the other. Relative resistance to change – the behavioral analogue of mass – was assessed by disrupting behavior in both components and measuring the proportional change in response rates. The disrupter was response-independent food presented during the inter-component intervals (ICIs). The red and blue ovals in the le ft portion of Figure 1 highlight the changes in response rates maintained on the VI 60 s and VI 180 s components, respectively, during the first disrupter test, with food presented response-independently during the ICI on a variable time 60-s schedule. The red and blue bars in the right portion of the figure show the decreases in response rates relative to baseline rates (i.e., rate during disruption/rate during baseline). Behavior during the component with the leaner schedule (blue bar) was disrupted to a greater extent (approximately 45% of baseline) than behavior in the richer component (red bar, approximately 82% of baseline), that is, behavior in the richer component was more resistant to change.

The remainder of the Nevin (1974) figure shows successive replications of this effect with disrupters of varying magnitudes. The initial test, however, is sufficient to illustrate the main points of interest for the present discussion. First, the multiple VI VI schedule arranges a situation in which a disrupter can be applied equally to two operants occurring in contexts of richer versus leaner obtained reinforcement. Second, any differences in baseline response rates are factored out of the resistance-to-change measures by expressing disruption as the test/baseline response rate ratio (in terms of the metaphor, the deceleration measure is relative to the initial velocity).

The second example from the basic research laboratory is Nevin, Tota, Torquato, and Shull (1990), Experiment 1, Condition 2. Conditions in a multiple -schedule disrupter paradigm were arranged such that the contingencies producing the difference between richer versus leaner obtained reinforcer rates were independent of the subject's responding. The schedule in one component was VI 60 s, and in the other component it was also VI 60 s but with a superimposed variable time (VT) 30 s schedule in which additional reinforcers were presented every 30 s on average, independently of responding. Thus, the response-reinforcer relations were the same in both components (VI 60 s), but the stimulus-reinforcer relations were different: The stimuli (key colors) for the VI + VT and VI-only components were correlated with richer and leaner overall rates of reinforcement, respectively. The clinician may note that the superimposed VT schedule in one component is equivalent to the “non-contingent reinforcement” (NCR) intervention sometimes used in applied behavior analysis (e.g., Vollmer, Iwata, Zarcone, Smith, & Mazaleski, 1993), a point we will return to later.

The right portion of Figure 2 shows part of the data presentation from Nevin et al. (1990). Experiment 1 (p. 363), for five sessions in which the disrupter was pre-session feeding. The filled points within the red oval show the data for a representative subject, with proportion of baseline in the richer component plotted against proportion of baseline in the leaner component. The right portion of the figure shows the data displayed in the bar-graph format used above for the Nevin (1974) study.

These results show consistently greater resistance to disruption by prefeeding in the VI + VT components. Thus, the primary determinants for resistance to change were stimulus-reinforcer relations: the characteristic overall rates of reinforcement associated with the stimuli that signaled the multiple-schedule components.

Behavioral momentum theory has inspired a great deal of additional basic research, but the core findings summarized above are sufficient anchoring points for the research with IDD populations to be reviewed below. Nevin and Grace (2000) provides an excellent compilation of basic research, interpretation, and commentary. More recently, behavioral momentum theory has been extended to analyze matching-to-sample performances (Nevin, Milo, Odum, & Shahan, 2003) and observing behavior (Shahan, 2002; Shahan, Magee, & Dobberstein, 2003; Shahan & Podlesnik, 2005), including applications of momentum theory in quantitative models of attending (Nevin, Davison, & Shahan, 2005) and remembering (Nevin, Davison, Odum, & Shahan, 2007).

Basic Laboratory Research in Humans with IDD

As noted above, this review will focus on research with IDD populations and with emphasis on studies using the multiple-schedule-disrupter paradigm or closely related variations. The studies described below all incorporated three important elements of the paradigm. First, the experimental conditions included a well-controlled comparison of response rates in alternating signaled contexts of relatively richer and leaner obtained reinforcement. Second, a disrupter test was applied equally to both contexts. Third, the dependent measures were test/baseline response ratios in the two contexts. For this reason, we will not include research that was inspired by momentum theory but conducted with procedures that depart significantly from the multiple-schedule-disrupter paradigm; examples of these types of studies include extensions to stimulus control in discrimination reversal learning (Dube & McIlvane, 2002) and to reinforcer rate adjustments (e.g., “high-p” procedures) to make compliance with requests more likely (e.g., Mace et al., 1988; McComas, Wacker, & Cooper, 1998; cf. Nevin, 1996) or increase spontaneous social initiations (Zanolli & Daggett, 1998).

The studies are not presented in chronological order, but rather along a continuum of methods and settings that represents a bridge from the basic laboratory to applied research. Thus, the pioneering work described in Mace et al. (1990) does not appear in the first section, although it was the first study to demonstrate in individuals with IDD the reinforcer rate effects on resistance to change predicted by momentum theory.

Two papers reported systematic replications of the basic research findings in a human operant laboratory using a multiple -schedule-disrupter paradigm (Dube, Mazzitelli, Lombard, & McIlvane, 2000; Dube, McIlvane, Mazzitelli, & McNamara, 2003). The procedures in both studies were very similar and they will be reviewed together. Most of the 12 participants were in the moderate range of intellectual disability with a few exceptions in either direction, almost all had diagnoses of autism spectrum disorder and/or mental retardation, and most were residential students. Richer and leaner contexts were defined by identical VI schedules in the multiple-schedule components, with a VT schedule superimposed in one component (as in Nevin et al., 1990). This comparison, VI versus VI + VT, constitutes a strong test of the momentum phenomenon because the response-reinforcer relations are the same in both components; only the stimulus-reinforcer relations are different. For practical reasons, the procedures in these human studies differed from those with pigeons in several important ways:

Reinforcers

The experiments used generalized conditioned reinforcers, probably the most often used form of tangible reinforcement in special education settings. Three of the participants who routinely used money in their daily lives earned points during sessions and the points were exchanged for money after sessions. The remaining participants were taught in preliminary sessions to accumulate poker-chip tokens and exchange them for their choices among a variety of items such as toys and snack foods. These participants were familiar with token-exchange systems from their special education programs. After training with the tokens to be used in the lab, participants were a given a preliminary test to verify that presentation of a token in fact functioned as a conditioned reinforcer. This reinforcer function test presented a series of concurrent choices between responses that did or did not produce tokens (see Dube et al., 2003 for details). The importance of such a pre-test was confirmed when one potential participant was found to be indifferent to token presentation and was thus removed from the study.

Reinforcer schedules

Experimental sessions were conducted at residential schools during the school day. Participants were typically available to leave their regular classroom activities for periods of 15 to 20 min, and so the experimental sessions themselves had to be about 10 min in duration. This approximates the average duration of classroom instructional episodes for many students with moderate to severe IDD. Also, we have found in previous research that participants (who are alone in the experimental space) may stop responding (e.g., and engage in stereotypy) if the overall rate of reinforcement is too low. For these reasons, the overall density of reinforcement in these studies was much greater than that for the studies with pigeon subjects: The baseline schedules were VI 10 s and VT 7 s in Dube et al. (2000) and VI 12 s and VT 6 s in Dube et al. (2003).

Stimuli and responses

The research used computer software that implemented the procedures as a computer game appropriate for individuals with IDD. For most participants the multiple-schedule stimuli were 2 × 2 cm animated color icons depicting balloons or gift-wrapped packages in the left or right side of the screen, respectively, and with different background colors. Five identical icons appeared to float around in a designated portion of the screen. When a participant touched an icon on the screen, it disappeared and a new one appeared in a different location. When a reinforcer was scheduled to follow a response, the icon disappeared in an animated explosion. If the reinforcer was a token, the icon was replaced by an image of a token that fell to the bottom of the monitor screen and disappeared as a real token was dispensed onto the tabletop. If the reinforcer was money, a counter was displayed on-screen. When one early participant, an adolescent boy, said he was not interested in “a little kid's game,” we developed a version of the software with red and blue spaceships and a jet-fighter type joy stick that was used for several of our adolescent participants.

Disrupter procedure

Disrupter procedures for the great majority of basic studies with pigeons arranged prefeeding, response-independent food presentations during inter-component intervals, or extinction. None of these were appropriate for our studies. Because we used a generalized conditioned reinforcer, disrupters that affected motivational operations would be unsuitable. The sessions seemed too short for extinction tests and our participants (unlike pigeons) were free to discontinue participation. An alternative disrupter procedure was suggested in Nevin, Mandell, and Yarensky (1981). In their study, multiple chained schedules were signaled by red, green, yellow, or violet illumination of the side keys of a three-key panel. During disrupter tests, the center key was occasionally lit white while one of the side keys was also illuminated, and a single peck to the center key produced access to food. This signaled concurrent reinforcement reduced the rates of responding to the other keys, even though relatively little time was required to collect the additional reinforcers. Pilot work suggested to us that signaled concurrent reinforcement would produce little disruptive effect, so we used an unsignaled version of the procedure in which a third type of icon was concurrently presented in the center area of the screen for an entire component, with reinforcers available for responses to it on a VI 7 s (Dube et al., 2000) or VI 8 s (Dube et al., 2003) schedule. That is, the center stimulus was an alternate source of intermittent reinforcement that competed with responding to the multiple-schedule stimuli (similar to the concurrent distracting stimulus in Mace et al., 1990).

Disrupter test method

In the basic research literature, the disrupter is usually presented for an entire session (a requirement for prefeeding) and the test consists of a block of several successive disrupter test sessions. Mean response rates during disruption are compared to mean baseline response rates during a block of several baseline sessions prior to the test. This blocked-sessions strategy requires fairly stable baseline response rates, a common outcome under the controlled conditions of the basic research lab (e.g., see Figure 1). Interpretation of the data would be difficult if response rates during disruption fell within the range of baseline variability. We obtained stable baseline response rates in some of our participants; for example, Dube & McIlvane (2006) includes data for 1 participant collected with the computer-game procedures described above and a blocked-sessions test. We also, however, encountered some cases in which even liberal criteria for session-to-session variability in baseline response rates were not met after a substantial number of sessions (e.g., see Figures 3 and 4 in Dube et al., 2000). The sources of this variability were not clear. Generalized conditioned reinforcers were used in part to try to minimize fluctuations in motivational operations, but the value of our tokens to the individual participants may nevertheless have changed from day to day. Other sources of variability may be related to aspects of our participants' lives outside of the research environment over which we had no control; examples include level of fatigue, current status within behavior intervention programs, stress resulting from disturbing events immediately prior to the session, anticipated events scheduled to follow the session, and so forth. Because the goals of translational research include the validation of principles under conditions that approximate clinical situations, the response-rate variability in some participants seemed to be an inescapable fact of life that had to be circumvented procedurally.

We developed a within-session test procedure that allowed us to conduct disrupter tests despite day-to-day variability in baseline response rates. Test sessions began with baseline components as usual, but then disrupter test components with baseline and disrupter stimuli presented concurrently were included near the end of the session. The dependent measure was the same as that for between-session test procedures, rate during disruption / rate during baseline. The difference was that both baseline and disruption response measures came from the same session, and thus test/baseline disruption measures for rich and lean components were calculated for each session. The complete test series included five test sessions with baseline-only sessions interspersed. The within-session test procedure is analogous to the approach used in electrophysiology, where the problem of low signal-to-noise ratios is addressed by gathering data over a series of distributed measurements.

Results

The test data for 1 participant in Dube et al. (2003) were not interpretable because he responded only to the disrupter stimuli whenever they were available (i.e., complete disruption). Figure 3 shows the results for the remaining subjects from both Dube et al. (2000) and (2003). In all cases, the results show that resistance to change was greater in the VI + VT component as predicted by behavioral momentum theory. The magnitude of the difference varied across individuals, but all of the differences were in the predicted direction.

Ratio schedules and within-subject comparisons

Dube and McIlvane (2001) examined resistance to change in a laboratory analog of computer-based discrete-trials instruction. The participants were 2 individuals with severe intellectual disabilities. The reinforcers for this study were snack-food items; both participants regularly received edible items as reinforcers in their regular instructional programs. The results for both participants were consistent with the predictions of behavioral momentum theory and several features of the procedures extended the range of independent variables in laboratory study with IDD participants: The stimuli signaling the multiple schedule components were two different and distinctive discrimination tasks presented on touch-screen computer monitors. Progression through trials was self-paced and rate of completing trials was the dependent measure. Rich versus lean contexts were arranged by continuous reinforcement versus variable-ratio schedules, respectively.

Disrupters were both prefeeding and concurrently presented distracting stimuli (e.g., a video presented next to the computer screen), presented in blocked-sessions test series. Both disrupters were programmed for all test sessions and so the behavioral effects can not clearly be related to one or the other. Because the participants were not food deprived, however, it seems plausible that any disruptive effects of prefeeding may have resulted from temporary alterations in relative food preferences.

As in previous studies, the effects of disrupters were evaluated in conditions in which two components of a multiple schedule provided different obtained reinforcer rates. In addition, participants were tested in conditions in which the reinforcer rates were similar in both

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components of the multiple schedules. That is, relative reinforcer rate as a controlling variable for resistance to change was evaluated using within-subject manipulations.

Basic Research Paradigm in Non-Laboratory Settings

Two studies have implemented the multiple-schedule-disrupter procedures in human participants with IDD in non-laboratory settings. The first was Mace and colleagues (1990), with 1 adult participant who had severe IDD and 1 at the low average range of intellectual functioning. The sessions were conducted in residential group home settings, the response was sorting plastic dinnerware, and the reinforcers were popcorn or coffee. Different obtained rates of reinforcement were correlated with different colors of dinnerware, arranged in Part 1 of the experiment by different VI schedules for each component (as in Nevin, 1974) and in Part 2 by equal VI schedules in each component with a superimposed VT schedule in one (as in Nevin et al., 1990, Experiment 1, Condition 2). Resistance to change was measured in blocked-session disrupter tests by introducing an interesting video during sorting. In both parts of the experiment, and for both subjects, the rate of sorting fell for both colors, but rate decreased less for the color that was correlated with the higher rate of reinforcement.

Parry-Cruwys et al. (in press) reports a systematic replication of Mace et al. (1990, Part 1) with several extensions. Participants were 6 children (ages 4 to 13 years) with diagnoses of autism spectrum disorders or related neurodevelopmental disabilities. Sessions were conducted in participants' special education classrooms at the desk or table where they usually worked and while regular classroom activities were ongoing with the other students in the class. All of the stimuli and responses were typical for the classroom, including academic tasks (e.g., math worksheets) or leisure activities (e.g., jigsaw puzzles), and the stimuli used for within-sessions disrupter tests were items of interest to the participants such as toys, books, or videos. Rich versus lean contexts were arranged by multiple VI 7-s VI 30-s schedules, and the reinforcers were those ordinarily used for each participant's classroom instruction, tokens (2 participants) or bits of snack foods (4 participants). The results were consistent with momentum theory for 5 of 6 participants.

Summary of Translational Research in IDD with Multiple-Schedule-Disrupter Paradigm

Table 1 summarizes the methods used in the studies reviewed above, with participants who had IDD and using multiple-schedule-disrupter procedures. Participants' ages ranged from 4 years to adult, levels of intellectual disability also spanned a wide range, from severe (e.g., unable to achieve a basal score on standardized tests) to borderline, and test settings included the laboratory, special education classroom, and group-home residence. The multiple-schedule procedures for 2 participants included ratio schedules, but the great majority of the work used variable-interval schedules, and both the unequal-VI (e.g., Nevin, 1974) and equal-VI with superimposed VT (e.g., Nevin et al., 1990) procedures for defining the relatively richer and leaner contexts are well represented.

Two areas in which the human research departs most clearly from the methods typical for non-human subjects are reinforcers and disrupters. Generalized conditioned reinforcers were used in the majority of cases (14 of 22 participants). Further, participants who received foods as reinforcers were not food deprived, and thus the biological significance of the consequence seems different in the human and non-human studies. In all instances, the disrupter in the human studies included the introduction of a concurrently available source of reinforcement. Disrupter-controlled responses produced the same reinforcer that followed baseline responses in about half of the cases (Dube et al., 2000; Dube et al. 2003), and in the remaining cases the reinforcer was something different, an event or item of interest to the participant, dubbed a “concurrent distracting stimulus” in Mace et al. (1990).

Reinforcer rate effects consistent with behavioral momentum theory were found in the great majority of subjects. Considering only the direction of the difference, test/baseline response rate ratios were higher in the richer component for 21 of 22 participants across all studies. If one considers only those instances in which the difference in ratios was greater than .05, there were positive results in 19 of 22 participants (excluding two in Dube et al., 2003; see Figure 3, participants NEW and HOT). The results of these studies, therefore, provide strong support for the conclusion that the differential resistance to change described in Nevin's behavioral momentum theory is a highly replicable finding in humans with IDD under laboratory conditions.

Applied Research in Humans with IDD

This section will describe one published study and one ongoing study that examined implications of behavioral momentum theory for clinical treatment strategies. Both studies were conducted with children with IDD who presented with behavioral problems of clinical significance, and in treatment settings that were usually used as analogue environments for functional analyses (Iwata et al., 1982/1994). The experimental sessions were structured in a manner similar to the typical functional-analysis approach – a series of successive 5-min conditions assessing the effects of antecedent and consequential manipulations on rates of problem behavior. The methods had some characteristics in common with multiple-schedule-disrupter procedures: (a) the studies examined the effects of interventions designed specifically to disrupt the problem behavior, and (b) these disruptive effects were compared in alternating contexts of richer versus leaner reinforcement. The methods departed from typical multiple-schedule-disrupter procedures in that (c) the higher and lower reinforcer contexts were programmed in different, alternating sessions, rather than in alternating components within the same session; and (d) the disrupters were programmed immediately following periods of richer versus leaner reinforcement, rather than during those periods.

Participants in the first study, Ahearn et al. (2003), were 3 boys (ages 4 to 9) with diagnoses of autism spectrum disorders who exhibited vocal or manual stereotypy. Results of functional analyses indicated that the behaviors were maintained by automatic reinforcement. One treatment approach for automatically reinforced aberrant behavior is known as noncontingent reinforcement (NCR) or environmental enrichment. Such treatment arranges for competition between the stimulation that arises from the problem behavior and some alternate source of reinforcement added to the environment. Research shows that such treatment interventions may successfully reduce the levels of problem behavior (reviewed in Rapp & Vollmer, 2005). A behavioral momentum perspective, however, raises the possibility that such treatment may also increase the persistence of the behavior, as suggested by the superimposed VT schedules in basic research studies comparing VI versus VI + VT.

In Ahearn et al. (2003), initial preference assessments were used to identify two items or activities that each participant would choose to engage with at least 70% of the time (suggesting that they were reinforcers) and also reduced levels of stereotypy during engagement (slinky, videos, etc.). Sessions included three conditions: Baseline, in which an experimenter was present but did not interact with the participant; an added-reinforcer VT condition which was the same as Baseline but with the addition of intermittent and limited access to one of the preferred items on a VT schedule; and a disrupter Test condition, also the same as Baseline but with the addition of continuous access to the second preferred item. Sessions alternated between sequences that included Baseline-VT-Test or Baseline-Baseline-Test, and continued for at least three repetitions of each sequence. Comparisons of target behavior rates in the second condition of each sequence (exclusive of time engaging with the preferred item) verified that the added reinforcers in the VT condition did in fact reduce rates of stereotypy. Comparisons of target behavior rates in the third condition of each sequence, however, showed that stereotypy was more resistant to disruption in Test conditions when Test followed a VT condition. These results suggest that the benefits derived from treating stereotypy with interventions such as NCR may come with associated costs. As clinicians develop treatment strategies, cost/benefit trade-offs may be worth consideration when planning when and how to implement the interventions.

As indicated by the results of Ahearn et al. (2003), enriched environments may produce a somewhat counter-intuitive outcome: Problem behavior becomes less frequent but more resistant to change because of the increased density of reinforcement in the context in which the problem behavior occurs. Similarly, function-based interventions such as differential reinforcement of alternative behavior (with the functional reinforcer maintaining problem behavior delivered for alternative behavior) might proximally decelerate problem behavior but ultimately produce behavior that is more persistent (e.g., Mace, 2000). This implication of the momentum metaphor seems to conflict with the partial reinforcement extinction effect (PREE), wherein behavior tends to extinguish more slowly following intermittent reinforcement than following continuous reinforcement (Mackintosh, 1974). There are many discussions of this seeming conflict, some suggesting that methodological differences account for the discrepant predictions while others note that behavior in extinction presents a unique situation in which the contingency and reinforcer density are simultaneously altered (see Branch, 2000; Shull & Grimes, 2006, for further discussion).

The notion that intermittently reinforced behavior may extinguish more slowly than continuously reinforced behavior could be applied clinically. Standard functional analysis procedures (Iwata et al., 1982/1994) introduce continuous reinforcement for problem behavior most likely maintained by intermittent schedules in the natural environment. It is possible that this continuous reinforcement of an otherwise intermittently reinforced behavior will produce a more rapid deceleration of problem behavior when a function-based treatment is imposed within the treatment setting. From the behavioral momentum perspective, however, one would make the opposite prediction. We have initiated a study (MacDonald, Roscoe, Ahearn, & Dube, 2006) whereby socially functioned problem behavior was exposed to either continuous or intermittent reinforcement prior to a brief exposure to extinction. Participants included 2 children with autism diagnoses (7 and 8 years old) who exhibited problem behaviors (aggression, hand biting) maintained by attention according to the results of a functional analysis. In sessions consisting of successive 5-min conditions (as in Ahearn et al., 2003), participants were exposed to sequences that included either (a) continuous reinforcement of problem behavior prior to extinction, or (b) intermittent reinforcement of proble m behavior prior to extinction, and for three repetitions of each sequence. Results showed that behavior was more persistent in extinction for both children following continuous reinforcement relative to the intermittent reinforcement condition. In fact, bursting (behavior occurring at a higher level in extinction relative to the preceding reinforcement condition) was more likely to occur following the continuous reinforcement condition. Though additional replication of this outcome is necessary to determine its reliability, it suggests that the momentum metaphor is a more accurate predictor of behavior transitioning to extinction than is the PREE.

Some Questions for Further Research

This section will outline a few questions for further research using the multiple-schedule disrupter paradigm or the functional analysis variation described above. For basic research studies conducted in the laboratory, two variables of possible interest are duration of baseline exposure and incorporation of differential outcomes procedures. For applied research studies, two possibilities include comparisons of the effects of matched versus unmatched added reinforcers on stereotypy and continuous versus intermittent negative social reinforcers on extinction of problem behavior.

Basic research

How does duration of exposure to baseline training conditions influence the development and magnitude of behavioral momentum effects? In the basic research literature, pigeons are often given approximately 50 sessions of exposure to the multiple-schedule baseline prior to disrupter tests. In contrast, most studies with humans with IDD have provided less training, ranging from as few as 6 to 10 sessions (Dube & McIlvane, 2003; Mace et al., 1990) to as many as 17 to 20 (Dube et al., 2003) and found somewhat greater inter-subject variability in the magnitude of the effect. (One exception in the human studies is Dube et al. [2000], in which 2 participants with strong positive results had over 100 session of baseline exposure prior to tests.) Further, the research with humans thus far has always included equal training histories for rich and lean components.

Research on baseline exposure durations may help to inform application efforts. For example, maladaptive behaviors may have long and rich histories of reinforcement whereas alternative adaptive behavior acquired in therapy may have a much shorter and likely leaner history. The research laboratory offers an environment in which the relative durations of exposure to the rich and lean multiple-schedule components can be manipulated and controlled prior to disrupter tests. On its face, and considering only aggregate reinforcer history, one might predict a stronger effect when the rich component is given the long history (with time, the rich get richer and thus rich/lean differences are magnified) than when the lean component is given the long history (with time, the lean get richer and thus rich/lean differences are diminished). However, it is also possible that the history of reinforcement outside of the rich versus lean context does not contribute to building behavioral mass (e.g., Cohen, 1998) and/or factors related to recency, novelty, and so forth may mitigate history effects.

Basic research

Will the use of distinctive reinforcers for multiple-schedule components increase the magnitude of effect or decrease inter-subject variability in IDD research? In discrimination learning, differential outcomes procedures arrange for different and distinctive reinforcers to follow correct responses to different stimuli. Research studies comparing differential outcomes to common outcomes (the same reinforcer for all correct responses) report faster acquisition and/or higher accuracy when delays are inserted between stimulus and response (reviews in Goeters, Blakely, & Poling, 1992; Urcuioli, 2005). Similar facilitation has been shown in humans with IDD (Estevez, Fuentes, Overmier, & Gonzalez, 2003; Litt & Schreibman, 1981). In the multiple -schedule -disrupter procedure, the richer and leaner components are signaled by different stimuli during both baseline and disrupter tests, and thus the test outcomes depend in part on the discrimination of these stimuli. In the basic research laboratory, one could conduct a controlled comparison between the standard procedure with the same reinforcer(s) in both rich and lean components, to a differential-outcomes procedure with qualitatively different (but equally preferred) reinforcers in the rich and lean components. It seems reasonable to ask whether a procedural manipulation that (a) has been shown to improve stimulus discrimination and (b) provides additional, highly salient stimuli correlated with the components (i.e., the reinforcers themselves) may lead to more consistent results in populations known for discrimination learning difficulties.

Applied research

Is the increased persistence in stereotypy from added-reinforcer procedures differentially affected by matched versus unmatched stimuli? Applied treatment strategies for stereotypy that program added reinforcers sometimes distinguish between the apparently reinforcing stimulation produced by matched and unmatched stimuli. Matched and unmatched stimuli are items that produce sensory consequences similar or not similar, respectively, to the hypothesized sensory consequences of the stereotypic behavior. Research shows that access to matched stimuli may be more effective in reducing the aberrant behavior than stimuli selected on the basis of preference assessments alone (e.g., Piazza, Adelinis, Hanley, Goh, & Delia, 2000). A follow-up to Ahearn et al. (2003) could compare resistance to disruption produced by VT access to matched versus unmatched stimuli. On the one hand, basic research indicates that resistance to change is related to the aggregate rate of reinforcement, including those of different qualities (Grimes & Shull, 2001). On the other hand, the intrinsic and self-generated nature of the maintaining consequences and response-reinforcer relations in stereotypy may make such behavior unusually sensitive to reinforcer quality or an interaction of reinforcer frequency and quality.

Applied research

Is resistance to extinction of problem behavior maintained by negative social reinforcement differentially sensitive to continuous versus intermittent schedules? The section above summarized findings from ongoing research on the effects of initiating extinction for problem behavior. Behavior was more resistant to extinction following continuous reinforcement than intermittent reinforcement. In the two cases described, the results of a functional analysis indicated that the behavior was maintained by attention, and thus the establishing operation was the presence of an adult who was not attending to the child. Problem behavior may also be maintained by negative social reinforcement in the form of cessation of demands. In such cases, the establishing operation is a continuing series of requests to perform some task or activity, and functional analysis results show that target behavior rates increase when the consequence for the behavior is escape from the requests. For both attention- and escape-maintained problem behavior, extinction requires the continuation of the establishing operation. For attention-maintained behavior, the adult remains passive and ignores the child; in contrast, extinction of escape-maintained behavior requires social interaction in the form of continued demands. Escape-maintained problem behavior is not uncommon in individuals with IDD, and research evaluating the extent to which reinforcer-rate effects may affect extinction seems worthwhile. Also of interest are related questions about the relative persistence of escape-maintained behavior in contexts of richer versus leaner non-social reinforcers.

Concluding Comments

Research has confirmed that the reinforcer-rate effects predicted by Nevin's behavioral momentum theory are a highly replicable, trans-species phenomenon. One is drawn to a theoretical model when its predictions are confirmed despite the fact that those predictions are sometimes counterintuitive or at odds with conventional wisdom. As the research has shown, momentum theory has this characteristic. One is drawn also to a theory when it finds applications in fields other than that in which it was originally developed. Momentum theory has this characteristic as well. Developed originally from work in the non-human behavior laboratory, the theory suggests a novel approach for dealing with problems of behavioral flexibility in clinical populations by pointing directly to reinforcement variables that may influence the degree to which behavior is resistant to change.

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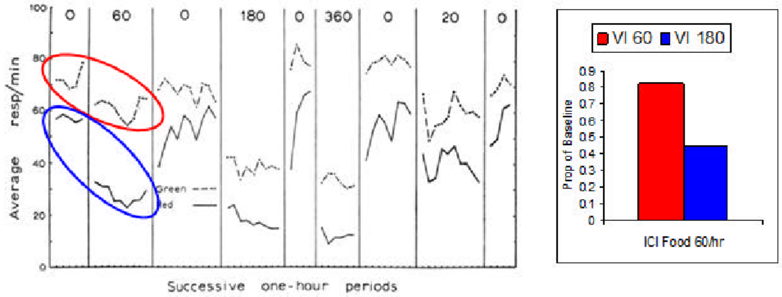

Figure 1.
Data from Nevin (1974, p. 392), Experiment 1.

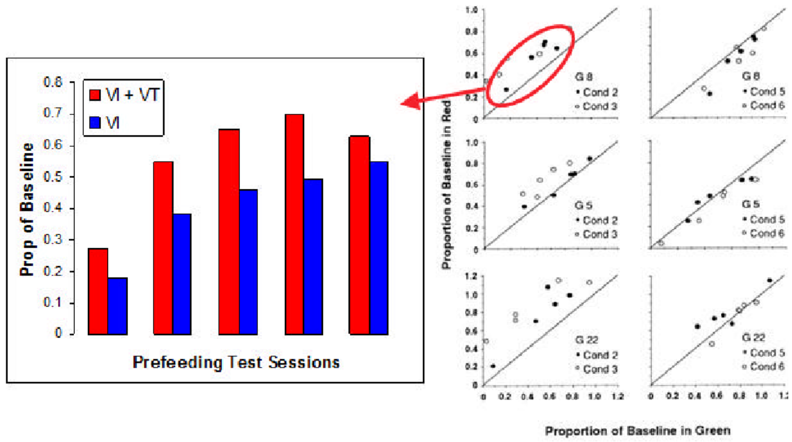

Figure 2.
Data from Nevin, Tota, Torquato, and Shull (1990, p. 363)

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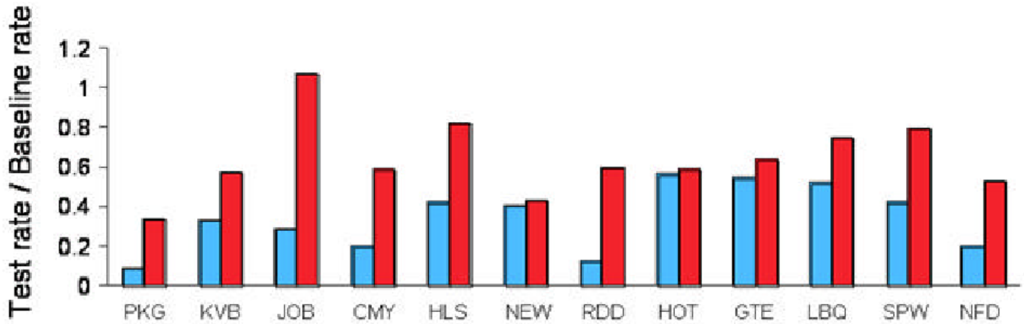

Figure 3.
Data from Dube et al. (2000) and Dube et al. (2003).

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Table 1

Summary of research conducted with multiple-schedule-disrupter paradigms in humans with intellectual and developmental disabilities

Study	N	Setting	Reinforcers	Response	Disrupter
Dube et al. (2003, *AJMR*)	10	Laboratory	mult VI 12 VI 12 + VT6 Points (money) Tokens	Computer game	Concurrently available reinforcers within computer game
Dube et al. (2000, *EAHBB*)	2	Laboratory	mult VI 10 VI 10 + VT 7 Tokens	Computer game	Concurrently available reinforcers within computer game
Dube & McIlvane (2001, *JEAB*)	2	Laboratory	mult CRF VR 4, mult CRF VR 15, mult CRF CRF Snack foods	Computer-based, self-paced discrete trials	Prefeeding and TV (video)
Mace et al. (1990, *JEAB*)	2	Residence (group home)	Part 1: mult VI 60 VI 240, Part 2: mult VI 60 VI 60 + VT 30 Snack foods	Sorting task	TV (video)
Parry-Cruwys et al. (in press, *JABA*)	6	Classroom	mult VI 7 VI 30 Tokens, Snack foods	Academic task or leisure activity	Preferred activities