The Psychological Record
https://doi.org/10.1007/s40732-020-00430-1

ORIGINAL ARTICLE

Behavior Momentum Theory and Humans: A Review of the Literature

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Abstract

Behavioral Momentum Theory (BMT) is often described as analogous to Newton's (1687) laws of motion. That is to say, similar to an object in motion continuing in motion unless acted upon by a force, responses occurring in a static environment will continue to occur at the same rate, unless presented with a disruptor (Nevin, Tota, Torquato, & Shull, *Journal of the Experimental Analysis of Behavior, 53,* 359–379, 1990). When evaluating response rates through a behavioral momentum framework, responding continuing after a change in reinforcer conditions is said to persist. Previous research conducted with nonhuman animals indicates greater response persistence following conditions with either higher reinforcer rates or higher reinforcer magnitudes (Nevin, *Journal of the Experimental Analysis of Behavior, 21*(3), 389–408, 1974; Nevin et al., *Journal of the Experimental Analysis of Behavior, 53*, 359–379, 1990). Although BMT's implications extend across human and nonhuman species, this literature review attempts to provide practitioners and researchers information regarding response persistence across various conditions with human participants.

Keywords Behavioral Momentum Theory · response persistence · response strength · disruptors · behavioral mass

Much of the Behavior Momentum Theory (BMT) literature compares Newton's first and second laws of motion (Newton, 1687) to the behavior of organisms (Nevin et al., 1990). Newton's first law of motion states that an object in motion remains in motion unless acted upon by an external force. The second law states an object's acceleration, or deceleration, is proportional to the relation between the object's mass and the force applied. Regarding Newton's first law, BMT suggests the object in motion described in Newton's laws is analogous to the response rate of a particular behavior, and the external force equates to the presentation of a disruptor (e.g., satiation or extinction). BMT also compares Newton's second law to increased or decreased response rates inversely related to the magnitude of obtained reinforcement and the disruptor. Thus, greater magnitudes of reinforcement (i.e., history of reinforcement) result in greater resistance to change (i.e., responses persistence) following the presentation of a disruptor (Nevin & Shahan, 2011).

Nevin et al. (1990) demonstrated that Pavlovian contingencies affect response persistence. Through stimulus–reinforcer pairings, the context associated with reinforcer delivery becomes conditioned, and its eliciting effect on the target behavior varies as a function of the conditioning history. However, others assert this relation between conditioning history and persistence to exist within an operant, rather than Pavlovian, conditioning contingency (Troisi & Mauro, 2017). In particular, proponents advocating an operant conditioning explanation for response persistence suggest the context associated with reinforcer delivery is not a respondent conditioned stimulus but instead serves as a discriminative stimulus signaling reinforcement availability and setting the occasion for responding. Regardless of whether behavioral persistence is attributed to aspects of Pavlovian or operant conditioning, responses occurring in the presence of contextual variables associated with greater rates of reinforcement often result in greater resistance following disruption (e.g., Nevin et al., 1990; Podlesnik & Shahan, 2009).

Variables shown to affect response strength (also referred to as persistence, and resistance to change) following the presentation of a disruptor involve the response's reinforcement

A portion of this research was supported by the Eunice Kennedy Shriver National Institutes of Child Health & Human Development of the National Institutes of Health under award 2R01HD069377. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

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Published online: 30 September 2020

history prior to disruption (Nevin, 2012). Newton's (1687) second law of motion described an object's acceleration or deceleration as directly proportional, and inversely related, to an object's mass and applied force. When discussing variables related to response strength from a BMT perspective, Nevin and Grace (2000) described behavioral mass as the behavior's history of reinforcement. In consequence, responses associated with relatively denser reinforcement histories exhibit greater resistance to change than responses associated with leaner reinforcement histories.

For example, responding associated with different stimuli (or different contexts upon which the response occurs) are paired with the respective reinforcement schedules occurring within each context. In this example, responses in Context A contact reinforcement on a variable interval (VI) 120-s schedule of reinforcement, whereas responses in Context B contact reinforcement on a VI 15-s schedule of reinforcement. Upon contacting a disruptor (e.g., extinction), BMT predicts the behavior associated with the richer reinforcement history (i.e., greater behavioral mass; Context B, in this example), will occur at proportionally higher response rates compared to baseline than the behavior associated with the leaner reinforcement history (e.g., Sweeney and Shahan, 2013).

Although widely researched within the framework of an experimental analysis of behavior with nonhuman animals (e.g., Igaki & Sakagami, 2004), the predictions made by BMT extends beyond the basic laboratory into translational and applied studies with human participants. For example, Parry-Cruwys et al. (2011) evaluated response persistence exhibited by students with autism in a special education classroom when simultaneously presented with distracting stimuli. In this experiment, researchers evaluated task persistence, such as writing responses, bead stringing, or puzzle building, on rich (VI 7-s) compared to lean (VI 30-s) reinforcement schedules. Five of the six participants exhibited behavior that was more resistant to extinction during the task associated with the richer reinforcement schedule, suggesting BMT can have clinical applications. Furthermore, Romani et al. (2016) evaluated the effect of different negative reinforcement schedules on the persistence of task completion exhibited by three participants who engaged in escape maintained problem behavior. In their study, all three participants demonstrated greater response persistence in the context associated richer reinforcement schedule when reinforcement was disrupted. Both of these examples provided researchers and practitioners with valuable information regarding BMT in applied settings.

Although research suggests BMT's predictions apply to humans as well as nonhuman animals, a comprehensive synthesis of the literature is needed to provide practitioners and researchers with information regarding persistence across various conditions. This synthesis could address several questions, such as what is represented in the literature regarding the percentage of participants exhibiting greater response persistence following disruption in rich versus lean conditions? We analyzed the literature regarding response persistence as it pertains to (1) factors that influence initial interventions (e.g., problem behavior contacting a disruptor following a rich compared to a lean schedule of reinforcement) as well as (2) factors that might influence persistence of trained responses (e.g., functional communicative responses and task completion). Therefore, the purpose of this review was to provide a comprehensive review of studies evaluating BMT using human participants by synthesizing (1) participant and setting characteristics, (2) experimental characteristics, and (3) experimental outcomes. Response persistence/resistance to change can be characterized in two ways: (1) resistance to change of a reinforced response when a disruptor is presented (often extinction), or (2) the reemergence of a previously extinguished response under various conditions (i.e., relapse). Although both are certainly important and hold practical implications, the current review focused on the first aspect of persistence.

Method

Search Procedures

The authors conducted a literature search following guidelines recommended by Moher, Liberati, Tetzlaff, Altman, and The PRISMA Group (2009). The first author searched a multidatabase search engine that included Social Sciences Citation Index, PsycINFO, Academic Search Complete, Science Citation Index, MEDLINE, Complementary Index, Academic OneFile, Science & Technology Collection, Education Research Complete, ERIC, Professional Development Collection, ScienceDirect, Psychology and Behavioral Sciences Collection, Sociological Collection, PsycARTICLES, and SocINDEX with Full Text using the term "behavior* momentum theory." Studies included in the review were not limited by publication year, but were included based on the following conditions: (1) peer-reviewed; (2) English-language; and (3) academic journals. After removing duplicates, the initial search provided 141 studies in which the author conducted additional reviews using the following three additional inclusion conditions: (4) included human participants across basic (conducted in laboratory settings to evaluate fundamental principles of behavior; Cooper, Heron, & Heward, 2007), applied (evaluating socially significant behaviors; Cooper et al., 2007), or translational (extending laboratory findings to clinical populations and problems; Lerman, 2003); studies (5) comparing two different conditions, such as rich versus lean schedules; and (6) evaluated the effect of a disruptor on behavior within the context of BMT. Articles were excluded if their primary purpose involved evaluating behavioral relapse phenomena (e.g., reinstatement, renewal, resurgence), as behavioral relapse occurs with a previously extinguished behavior (Podlesnik & Shahan, 2009). An initial abstract and title review resulted in 42 potentially eligible articles. The full-text screening excluded 30 articles with a remaining 12 articles meeting the criteria. From these 12 articles, the first author conducted an ancestral hand search using the same inclusion criteria listed above. The ancestral hand search involved reviewing every reference cited in the 12 original articles to determine whether cited studies also met the inclusion criteria. The final ancestral search resulted in an additional 12 articles for a total of 24 articles included in the review (see Fig. 1).

Coding Procedures

The first author coded descriptive participant and experiment characteristics (61 variables) of all included experiments within each study. In addition to descriptive characteristics, reviewers coded nine variables related to outcome variables. Participant characteristics included variables such as gender, age, and diagnosis. Experiment characteristics included variables such as experimental setting(s), implementer(s), target behavior(s), reinforcers, and disruptor(s). Experimental outcomes included coding persistence comparisons between independent variables across each dependent variable.

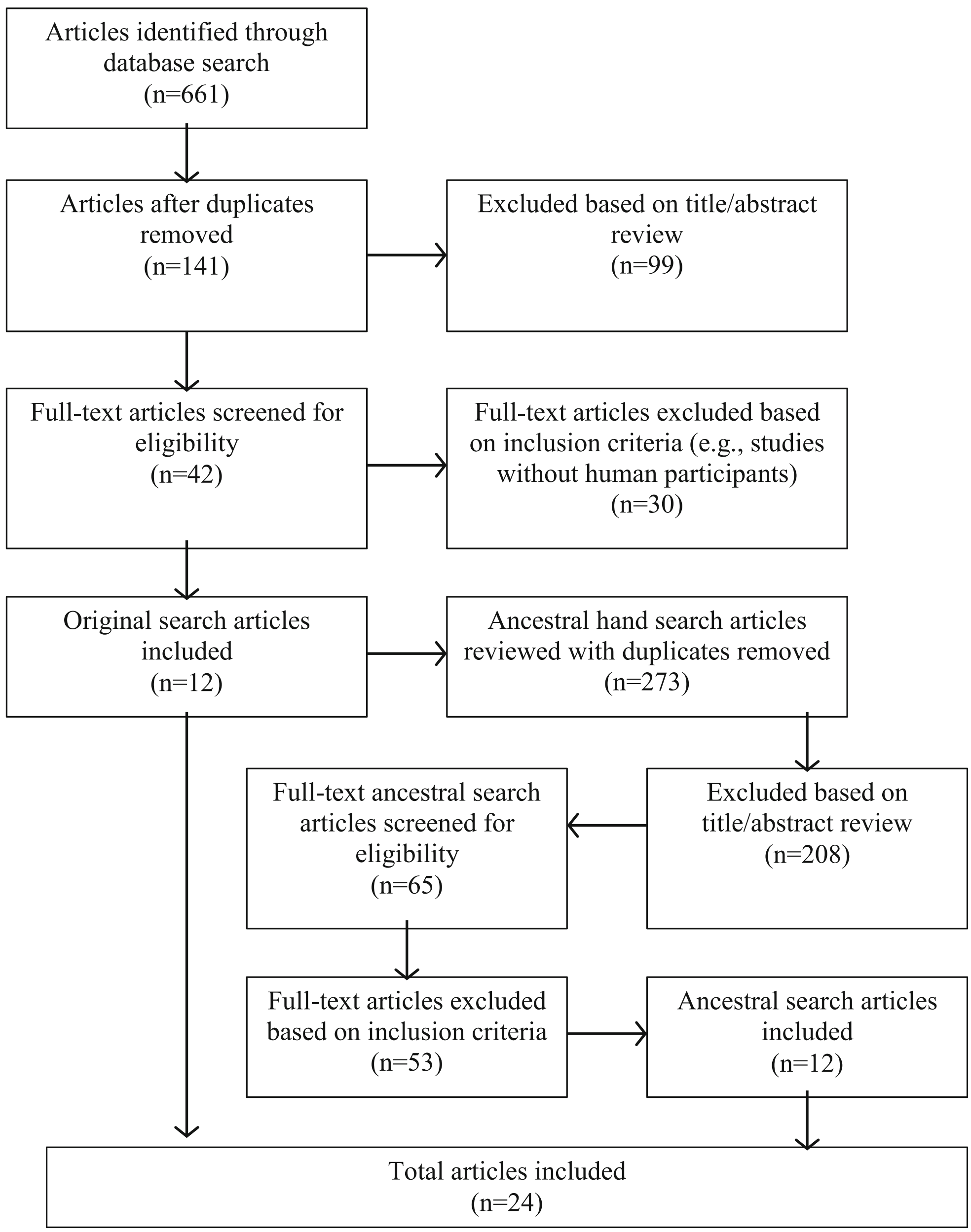

Fig. 1 Initial and ancestral search results

Participant and Setting Characteristics Participant and setting characteristics included gender, age, diagnosis, experimental setting, interventionists, and functional analysis results. When coding participant's ages, reviewers coded whether the participant fell between 0 to 5 years old, 6 to 12 years old, 13 to 18 years old, or if they were older than 18 years. Participant diagnosis codes included autism or pervasive developmental disorders (PDD), intellectual disability (ID), developmental delays (DD), multiple diagnoses, other diagnoses, or no diagnosis (i.e., participants were typically developing). Experimental settings included hospital rooms, therapy or laboratory rooms, classrooms, work facilities, or living rooms, kitchens, or bedrooms, which were also coded as additional settings. Interventionist codes included therapist/experimenter, teacher/paraeducator, or parent/caregiver. Functional analyses results included tangible, automatic, escape, attention, and multiply maintained.

Experimental Characteristics Experimental characteristics included dependent variables, reinforcers, signaled or unsignaled stimuli through the incorporation of a discriminative stimulus, and disruptors. Dependent variables included functional communicative responses (FCR), task completion, and problem behavior (e.g., aggression, self-injurious behavior, disruption). The FCRs included various mand modalities such as various augmentative alternative communicative devices (e.g., picture cards, tablets, microswitches), manual sign, and vocal requests. Reinforcer codes included escape, attention, tangible, tokens, food, food compared to tokens and an "other" category.

When coding whether researchers included stimuli associated with different experimental conditions, the reviewers noted whether different color task materials, different therapists, or different backgrounds were associated with different experimental conditions. Researchers coded "no" under the discriminative stimulus section if these components were not present in the experiment.

Disruptor codes included alternative stimuli, distractors, extinction, extinction and distraction, prefeeding, noncontingent reinforcement (NCR), or other distractors not falling into any of the six listed categories. Reviewers coded for extinction as the disruptor if the experiment incorporated a condition where a previously reinforced response no longer contacted reinforcement. Noncontingent reinforcement was coded when reinforcers were delivered independent of participant responding. Alternative stimuli were defined as stimuli signaling the availability of an alternative concurrent schedule of reinforcement. Distractors included the presence of items or activities such as preferred toys, movies playing, or the presence of an additional therapist. Prefeeding involved participant presession reinforcer consumption.

Experimental Outcomes Reviewers coded each comparison conducted within each experiment. For example, if an experiment compared the effect of rich versus lean schedules (e.g. VI 10-s versus VI 30-s) on FCRs and task completion, the authors coded results related to rich versus lean schedules on FCRs in addition to coding results for the effect on task responding. Independent variable comparisons included studies evaluating persistence of high versus low preferred mand modalities. For example, evaluating the effect of disruption on a more preferred mand modality such as a picture exchange card compared to a less preferred mand modality such as vocalizations. The review also coded rich versus lean schedules of reinforcement. For example, evaluating the effect of a rich (VI 30-s) versus lean (VI 60-s) schedule on response persistence, or evaluating the effect of a combined VI plus fixed time (FT) schedule compared to a VI schedule alone. Furthermore, experimental outcome codes also included coding results by disruptors (e.g., extinction, distractors, NCR).

Interobserver Agreement

A second graduate student conducted an identical literature search using the aforementioned search terms, inclusion criteria, and multidatabase search engine. A third graduate student coded 20.83% (N = 5) of included articles, and 21.21% of total experiments (N = 7), using identical participant, experiment, and outcome coding templates described above. Each experiment included 61 descriptive variables and nine results variables for each comparison. Interobserver agreement was calculated by dividing agreements by the number of agreements plus disagreements and multiplying by 100. The literature search, conducted by the second graduate student, resulted in 80% agreement. The second graduate student initially discovered 15 original articles meeting the inclusion/exclusion criteria. Following conversations discussing inclusion/exclusion criteria, the first author and graduate student agreed on 12 articles meeting criteria. Coding, conducted by the third graduate student, resulted in 93.62% overall interobserver agreement for participant, experiment, and outcome codes.

Results

Participant and Setting Characteristics

The review comprised 151 experimental evaluations (see Table 1). Reviewers coded participant characteristics every time the participant engaged in an experimental evaluation. For example, Vargo and Ringdahl (2015) included multiple experiments with four to five participants. Some participants were included in more than one experiment. In these instances, their participant codes were included for each experiment. Likewise, Lionello-DeNolf, Dube, and McIlvane (2010) evaluated the effect of three different disruptors (alternative stimulus, prefeeding, distractor) with six participants and an additional distractor with five participants. When evaluating Lionello-DeNolf et al.'s (2010) study, reviewers included participant demographic and setting codes for each disruptor evaluation for a total of 23 participant evaluations.

Participant ages ranged from 1 to 68 years old with more than half of the participants under the age of 18 (64.9%). Of the 151 participants, 69.54% (*N* = 105) were male, 23.18% (*N* = 35) were female, and 7.28% (*N* = 11) did not have a specified gender reported. The review included participants diagnosed with intellectual disability (*N* = 38), autism or pervasive developmental disability (*N* = 70), developmental delays (*N* = 3), or multiple disabilities (*N* = 15). In addition, the experiments also included 20 participants without reported disabilities, which primarily participated in basic or translational experiments. For example, Vargo and Ringdahl (2015) evaluated resistance to change with unconditioned and conditioned reinforcers with typically developing children.

Table 1 Participant and Setting Characteristics

Characteristics	N	Percent
Gender		
Male	105	69.54
Female	35	23.18
Not reported	11	7.28
Age		
0–5	29	19.21
6–12	35	23.18
13–18	34	22.52
>18	49	32.45
Not reported	4	2.65
Diagnosis		
ID	38	25.17
Typical	20	13.25
Autism/PDD	70	46.36
Developmentally Delayed	3	1.99
Other	5	3.31
Multiple	15	9.92
Setting		
Hospital room	1	0.66
Therapy/experimental room	123	81.46
Living room, kitchen, bedroom	10	6.62
Classroom	7	4.64
Work facility	10	6.62
Interventionist		
Therapist/experimenter	150	99.34
Teacher/paraprofessional	1	0.66
Parent/Caregiver	0	0.00
Functional analyses results		
Tangible	8	5.30
Automatic	0	0.00
Escape	3	1.99
Attention	7	4.64
Multiply maintained	0	0.00
Did not conduct	133	88.08

Note. ID = Intellectual Disability, PDD = Pervasive Developmental Disorder

The review yielded five different settings in which the experiments were conducted. One hundred twenty-three experiments were conducted in a therapy or experimental room (81.46%), 10 experiments were conducted in a living or bedroom (6.62%), and 7 experiments were conducted in a classroom setting (4.64%). Furthermore, therapists or experimenters conducted the majority of the included experiments (*N* = 150, 99.34%), whereas a teacher/paraprofessional conducted one experiment (0.66%).

The review included results of functional analyses when reported. A tangible function was reported for 5.3% (*N* = 8) of participants, an escape function was reported for 1.99% (*N* = 3) of participants, and an attention function was reported for 4.64% (*N* = 7) of participants. In addition, 0% of participants exhibited automatic or multiply maintained problem behavior; 88.08% (*N* = 133) of participants did not have a functional analysis conducted.

Experimental Characteristics

As previously described, dependent variables included FCRs, problem behavior, or task completion (see Table 2). Task completion included experiments examining participant responses involving computer navigation such as Dube, Thompson, Silveira, and Nevin's (2017) study involving a computer game written in Python requiring participants to move icons using keys on a modified keyboard, or studies such as Vargo and Ringdahl's (2015) evaluating tasks such as number or letter tracing, and stringing beads. Over 80% of the included experiments evaluated task completion (*N* = 127), whereas the remaining 24 experiments evaluated problem behavior (*N* = 17), FCRs (*N* = 3), or a combination of problem behavior and FCR (*N* = 4). The type of reinforcers in each experiment are also noted in Table 2, with almost half of the experiments (43.36%) using tangible items (*N* = 67) and 35.76% using tokens (*N* = 54).

Experiments included disruptors such as extinction (*N* = 52, 34.44%). Thirty-one (20.53%) experiments evaluated the effect of distractors such as videos (e.g., Mace et al., 1990), and 12 experiments (7.95%) evaluated the effect of prefeeding. For example, during Vargo and Ringdahl's (2015) prefeeding disruptor phase, participants consumed food prior to beginning experimental sessions in addition to food consumption during intercomponent intervals.

Furthermore, 21.85% of the disruptors were coded as alternative stimuli. For example, Lionello-DeNolf and Dube's (2011) alternative stimulus test involved an additional stimulus associated with a VI 6-s presented concurrently with either the rich or lean components.

Of the evaluated experiments, 88.08% (*N* = 133) involved a discriminative stimulus and 11.92% (*N* = 18) did not. For example, Dube and McIlvane (2001) used different colored backgrounds to signal different conditions (i.e., a white background for Task A and a black background for Task B). Likewise, Lionello-DeNolf and Dube (2011) used different computer icons associated with either the rich or lean conditions (e.g., balloon and gift).

Experimental Outcomes

Experimental outcomes are summarized in Tables 3 and 4. Table 3 displays the number of comparisons and the percent of comparisons displaying greater persistence across dependent variables. The independent variable comparisons are indicated with superscript numerals in the first column. The first independent variable comparison evaluates the effect of rich versus lean schedules on experiments evaluating problem behavior (*N* = 15) and task completion (*N* = 66). For example, Mace et al. (1990) compared the effect of a rich (VI 30-s) versus lean (VI 60-s) schedule on response persistence, but other researchers, such as Lieving, DeLeon, Carreau-Webster, Triggs, and Frank-Crawford (2018), evaluated the combination of a VI plus fixed time (FT) schedule compared to a VI schedule alone. Overall, the review discovered 73% of the included experiments indicated problem behavior responses persisted greater in rich compared to lean schedules. Likewise, 71% of task completion responses persisted in rich compared to lean schedules. In particular, comparisons involving DRA associated with rich versus DRA lean reinforcement schedules display greater persistence in 75% of included comparisons.

However, when comparing the effect of different disruptor magnitudes on response persistence, task completion responses persisted more in conditions associated with lower magnitudes of reinforcement. For example, in Carr, Bailey, Ecott, Lucker, and Weil's (1998) study, task completion was disrupted with noncontingent reinforcement of low, medium, or high reinforcer magnitudes. In these comparisons, the participant's task completion persisted at a greater rate when disrupted with the lower reinforcer magnitude.

Independent variable comparisons also included experiments evaluating persistence of high versus low preferred mand modalities. For example, Ringdahl et al. (2018) evaluated persistence of FCRs associated with high preferred versus low preferred mands. In this example, reviewers coded the number of participants evaluated in each comparison as well as the number of participants exhibiting greater response persistence with high preferred versus low preferred mands (86%).

Table 4 displays experimental outcomes by studies and also includes dependent variables, disruptors, the number of participant evaluations, independent variable comparisons, as well as comparison results. In the second column, the author identifies independent variable comparisons. For example, Carr et al. (1998) evaluated the effect of a noncontingent reinforcement schedule (NCR) on low verses medium, low versus high, and medium versus high magnitude reinforcers. The third column indicates the dependent variable, which the author coded as task completion in the Carr et al. (1998) experiment. Finally, the last five columns indicate the number of participants (*N*), and the percent of participants with greater persistence in the first comparison condition. Table 4 also includes the coded results by disruptors. For example, Lionello-DeNolf et al. (2010) evaluated response persistence on rich versus lean schedules when presented with an alternative stimulus, prefeeding, and distraction.

Table 2 Experimental Characteristics

Characteristics	N	Percent
Dependent variable		
FCR	3	1.99
Task completion	127	84.11
Problem behavior	17	11.26
Problem behavior and FCR	4	2.65
Reinforcer		
Other	1	0.66
Food versus tokens	13	8.61
Escape	9	5.96
Attention	7	44.37
Tangible	67	43.36
Token	54	35.76
Discriminative stimulus		
Yes	133	88.08
No	18	11.92
Disruptors		
Extinction and distraction	4	2.65
Extinction	52	34.44
Other	9	5.96
Alternative stimulus	33	21.85
Distraction	31	20.53
Motivating operation manipulation	12	7.95
Noncontingent reinforcement	10	6.62

Note. FCR = Functional communicative response.

Discussion

The current review included 24 peer-reviewed articles evaluating BMT with human participants. Many of the experiments evaluated effects of rich versus lean schedules of reinforcement on response persistence. In addition, a large number of experiments evaluated response persistence when extinction functioned as a disruptor. Most of the reviewed studies took place in experimental (e.g., human operant laboratory) or therapeutic (e.g., in-patient unit) settings. Few experiments took place in more naturalistic settings, such as classrooms, homes, or work settings." The review indicated greater response persistence following rich (i.e., high rate and/or high magnitude) compared to lean (i.e., low rate and/or low magnitude) reinforcement schedules. The aforementioned results align with results reported in the basic, nonhuman research literature. For example, Nevin (1974) showed greater persistence following relatively high rates or relatively high magnitude reinforcement schedules.

Implications for Practice

The current review discovered 17 experiments evaluating response persistence of problem behavior. It is interesting that 15 of these 17 experiments evaluated the effect of extinction as a disruptor whereas the remaining two evaluated the effect of motivating operation (MO) manipulation. For example, Berg et al. (2000) evaluated the effect of presession attention on responding during attention session of a functional analysis for behavior that was determined to be maintained by attention. Eleven of the 15 experiments evaluating response persistence of problem behavior in rich compared to lean schedules resulted in greater persistence in the richer schedule of reinforcement. As a result of this finding, practitioners might consider the implications of implementing an extinction component in contexts in which problem behaviors contacts rich schedules of reinforcement. For example, practitioners should be aware that implementing an extinction-based procedure following a rich reinforcement schedule might require a longer time to be effective when compared to extinction-based procedures implemented following lean reinforcement schedules.

On the other hand, the review also discovered 71% (*N* = 50) of studies demonstrated response persistence of FCR or task completion responses in rich compared to lean schedules. Therefore, when programing alternative responses (e.g., FCR), practitioners might consider programing rich schedules of reinforcement for alternative behaviors. For example, if teaching a learner to mand, the literature suggests the mand is more likely to persist in the face of disruption, if the mand contacted a richer schedule of reinforcement prior to disruption. Furthermore, because it is likely a newly acquired skill such as manding might contact disruptors outside of intervention contexts, programing rich schedules of reinforcement might create robust alternative behaviors, which are paramount for the learner's success.

Table 3 Persistence Comparisons across Independent and Dependent Variables

Independent Variable Comparison	Problem Behavior			Functional Communication			Task Completion		
	N	N 1>2	% >	N	N 1>2	% >	N	N 1>2	% >
Rich[1] vs. Lean[2]	15	11	73				66	47	71
DRA Rich[1] vs. Lean[2]							4	3	75
Presession Escape[1] vs. Pressession Play[2]	1	1	100						
Presession Alone[1] vs. Presession Play[2]	1	1	100						
High[1] vs. Low Preferred Mand[2]				7	6	86			
Unconditioned[1] vs. Conditioned[2]							13	4	31
Low[1] vs. Medium Disruptor Reinforcer Magnitude[2]							5	5	100
Low[1] vs. High Disruptor Reinforcer Magnitude[2]							2	2	100
Medium[1] vs. High Reinforcer Magnitude[2]							5	5	100
High[1] vs. Low Reinforcer Magnitude[2] (predisruption)							3	2	67
DRA[1] vs. DRO+DRA[2]							9	6	67
High[1] vs. Low Discrimination[2]							13	8	62
DRA[1] vs. NCR[2]							8	3	38
High[1] vs. Low Preferred Reinforcer[2]							1	1	100

Note. The superscript numerals 1 and 2 are used in the left column to arbitrarily designate treatment conditions and are used in subsequent columns to display results of the comparisons between the conditions. DRA = Differential Reinforcement of Alternative Behaviors; DRO = Differential Reinforcement of Alternative Behaviors; NCR = Noncontingent Reinforcement

Table 4 Study Outcomes

Citation	Comparison	DV	Disruptor	N	IV 1	% N	>	IV2
Berg et al. (2000)	PS ESC vs. PS Play	PBX	MO	1	PS ESC	100	>	PS Play
	PS Alone vs. PS Play	PBX	MO	1	PS Alone	100	>	PS Play
Carr, Bailey, Ecott, Lucker, & Weil (1998)	Low vs. Med Mag SR	TC	NCR	5	Low Mag	100	>	Med Mag
	Low vs. High Mag SR	TC	NCR	2	Low Mag	100	>	High Mag
	Med vs. High Mag Sr	TC	NCR	3	Med Mag	100	>	High Mag
Dube & McIlvane (2001)	Rich vs. Lean	TC	DIST	2	Rich	100	>	Lean
Dube & McIlvane (2002)	High vs. Low Discrimination	TC	SC	9	High	89	>	Low
Citation	Comparison	DV	Disruptor	N	IV 1	% N	>	IV 2
Dube, Thompson, Silveira, & Nevin (2017)	DRA vs. DRO-DRA	TC	EXT	5	DRA	60	>	DRO + DRA
	DRA vs. DRO-DRA	TC	EXT + DIST	4	DRA	75	>	DRO +DRA
Dube, Mazzitelli, Lombard, & McIlvane (2000)	VI + VT vs. VI	TC	ALT STIM	2	VI+VT	100	>	VI
Dube, McIlvane, Mazzitelli, & NcNamara (2003)	VI + VT vs. VI	TC	ALT STIM	13	VI + VT	87	>	VI
Kuroda, Cancado, & Podlesnik (2016)	DRA Rich vs. Lean	TC	DIST	4	Rich	75	>	Lean
Lambert, Bloom, Samaha, Dayton, & Kunnavatana (2016)	Rich vs. Lean	PBX	EXT (PBX)	1	Rich	100	>	Lean
Citation	Comparison	DV	Disruptor	N	IV1	% N	>	IV 2
Lerman, Iwata, Shore, & Kahng (1996)	Rich vs. Lean	PBX	EXT	3	Rich	67	>	Lean
Lieving et al. (2018)	VI+VT vs. VI	PBX	EXT	4	VI + FT	100	>	VI
Lionello-DeNolf & Dube (2011)	Multiple Schedule Rich vs. Lean	TC	ALT STIM	6	Rich	100	>	Lean
	Single Schedule Rich vs. Lean	TC	ALT STIM	6	Rich	33	>	Lean
Lionello-DeNolf, Dube, & McIlvane (2010)	Rich vs. Lean	TC	ALT STIM	6	Rich	50	>	Lean
	Rich vs. Lean	TC	PF	6	Rich	33	>	Lean
	Rich vs. Lean	TC	DIST	6	Rich	50	>	Lean
	Rich vs. Lean	TC	DIST	5	Rich	80	>	Lean
MacDonald, Ahearn, Parry-Cruwys, & Bancroft (2013)	Rich vs. Lean	PBX	EXT	4	Rich	100	>	Lean
Mace et al. (1990)	Rich vs. Lean	TC	DIST	2	Rich	100	>	Lean
	VI+VT vs. VI	TC	DIST	2	VI+VT	100	>	VI
Citation	Comparison	DV	Disruptor	N	IV 1	% N	>	IV 2
Mace, Mauro, Boyajian, & Eckert (1997)	Low vs. High Preferred SR	TC	Low Probability Request	1	High	100	>	Low
McComas, Hartman, & Jimenez (2008).	High vs. Low Mag	TC	EXT	3	High	67	>	Low
Parry-Cruwys et al. (2011)	Rich vs. Lean	TC	DIST	6	Rich	83	>	Lean
Ringdahl et al. (2018).	High vs. Low Preferred Mands	FCR	EXT	3	High Preferred	100	>	Low Preferred
	High vs. Low Preferred Mands	FCR	EXT	4	High Preferred	75	>	Low Preferred
Romani et al. (2016)	VI+VT vs. VI	TC	EXT	3	VI+VT	100	>	VI
	VI+VT vs. VI	PBX	EXT	3	VI	67	>	VI+VT

Table 4 (continued)

Citation	Comparison	DV	Disruptor	N	IV 1	% N	>	IV2
Saini & Fisher (2016)	High vs. Low S^D Discrimination	TC	EXT	4	Low Discrimination	75	>	High Discrimination
Citation	Comparison	DV	Disruptor	N	IV 1	% N	>	IV2
Sweeney et al. (2014)	rT NCR vs. rT DRA	TC	EXT	3	rT NCR	67	>	rT DRA
	No rT NCR vs. No rT DRA	TC	EXT	5	No rT NCR	40	>	No rT DRA
Thrailkill, Kimball, Kelley, Craig, & Podlesnik (2018)	Rich vs. Lean	TC	EXT	1	Rich	100	>	Lean
Vargo & Ringdahl (2015)	Food vs. Token SR	TC	EXT	5	Token	100	>	Food
	Food vs. Token SR	TC	DIST	4	Token	100	>	Food
	Food vs. Token SR	TC	MO	4	Food	100	>	Token

Note. ALT = Alternative; DIST = Distraction; DRA = Differential reinforcement of alternative behavior; DV = Dependent variable; EXT = Extinction; FCR = Functional communicative response; FCT = Functional communication training; IV = Independent Variable; MO = Motivating operation manipulation; NCR = Noncontingent reinforcement; NT = Novel Task; PBX = Problem behavior; PS = Presession; rT= analog sensory reinforcement; S^D = Discriminative Stimulus; STIM = Stimulus; TC = Task completion

Schieltz, Wacker, Ringdahl, and Berg (2017) described assessment and treatment decisions based on BMT. The authors focused on discrepancies between two ways behavior analytic maintenance effects are measured: (1) treatment effects probed over long periods of time under prevailing treatment conditions (Durand & Carr, 1991); and (2) evaluating behavioral persistence following the presentation of a disruptor (e.g., extinction; Nevin & Wacker, 2013). Schieltz et al. (2017) noted the former measurement system does not require an analytical evaluation directly tied to specific behavioral processes. However, the latter definition provides practitioners with a format to evaluate and program durable maintenance effects during treatment rather than conducting post-hoc treatment evaluations. Although DRA interventions demonstrate decreased levels of problem behavior and increased rates of appropriate behavior, maintenance of these effects are seldom reported (Schieltz et al., 2017). Moreover, when maintenance effects are reported, they are often reported as effects over time rather than a systematic analysis providing information regarding the circumstances in which maintenance is likely or unlikely to occur (e.g., Nevin & Wacker, 2013; Schieltz et al., 2017). Evaluating maintenance based on BMT (i.e., evaluating persistence following disruption) provides a thorough assessment and treatment framework based on underlying behavioral processes (Schieltz et al., 2017). The second maintenance measurement method described by Schieltz et al. (2017), requires evaluating the effect of systematically manipulating the target response's history of reinforcement (i.e., magnitude and rate) and the presentation of different disruptors.

Therefore, evaluating the effect of different reinforcement and disruptor variables might prove instrumental in programming high levels of treatment durability when designing and monitoring intervention plans. For instance, Ringdahl et al. (2018) indicated relatively preferred mand modalities (as demonstrated through a mand modality preference assessment) resulted in greater persistence when placed on extinction. Perhaps practitioners can use similar evaluations to determine responses more likely to exhibit greater persistence when challenged. Evaluating variables linked to BMT such as behavioral mass and various disruptors provide valuable information regarding treatment decisions. For example, assessing maintenance through a BMT framework might allow practitioners to program high levels of treatment durability. Furthermore, after evaluating persistence and determining a behavior to be resistant to disruptors, this analysis might also provide a framework to systematically discontinue services.

Implications for Research

When evaluating behavioral mass, the current review indicated researchers often evaluate the effect rich versus lean reinforcement rates on responding during disruption. Few reviewed experiments evaluated the effect of different reinforcer dimensions (e.g., magnitude) on response persistence. However, McComas, Hartman, and Jiminez (2008) evaluated the effect of high magnitude reinforcers compared to low magnitude reinforcers on persistence of computer clicks. McComas et al. discovered greater response persistence in the components associated with higher reinforcer magnitudes (i.e., greater number of points). No reviewed experiments evaluated delays to reinforcement and their impact on persistence. Therefore, future investigations might evaluate the effect of manipulating additional reinforcer dimensions prior to disruption. For example, though not specifically evaluating responding through a BMT framework, Athens and Vollmer (2010) manipulated three different reinforcer dimensions (quality, duration, delay) in a concurrent schedule arrangement. The authors discovered response allocation favoring the more advantageous schedule (e.g., higher quality reinforcers, longer duration exposed to reinforcers, or shorter delays to reinforcement) rather than behaviors associated with weaker reinforcer dimensions (e.g., lower quality, shorter duration, or longer delays to reinforcement). The results reported by Athens and Vollmer align with predictions made by matching law, a quantitative model of behavior that predicts response allocation under concurrent reinforcement schedule arrangements (Baum, 1974; Herrnstein, 1961), and also align with Trump, Ayres, Quinland, and Zabala (2020) literature review, which discovered effective treatment packages with concurrent schedules resulting in greater response allocation associated with the more favorable schedule. Given that they demonstrated that reinforcement schedule dimensions such as magnitude and delay to reinforcement affected response allocation, it may be interesting to see if these same dimension affect responding under schedule arrangements relevant to BMT (i.e., multiple schedule arrangements).

Similar to evaluating different reinforcer dimensions, few experiments evaluated different disruptor dimensions. When considering Newton's second law of motion, BMT states response strength is directly proportional and inversely related to reinforcement history and the magnitude of a disruptor (e.g., Nevin & Shahan, 2011). As previously discussed, BMT provides a framework for evaluating and predicting responding based on the target behavior's history of reinforcement and the presentation of a disruptor. Numerous experiments evaluated different factors related to behavioral mass, but little or minimal variation exists when examining the effect of different disruptors. Only 7.95% (N = 12) of the included experiments evaluated MO manipulation as a primary disruptor (e.g., prefeeding). Moreover, few researchers evaluated different disruptor magnitudes (e.g., different distractor volumes) or disruptor combinations, and only 20.53% (N = 31) evaluated the effect of distractors. Therefore, future investigations might consider quantifying and evaluating the effect of different disruptor magnitudes (e.g., quiet compared to loud disruptors), distractors (e.g., preferred compared to nonpreferred videos), and presession conditions (e.g., evaluating the effect of satiation and deprivation). For example, in applied settings, teachers might play music during independent work time; however, the effect of type of music or the music's volume has not been evaluated within the context of BMT.

In addition, this review discovered 127 experiments evaluating the effect of disruptors on task completion. It is interesting that all experiments involving typically developing individuals (N = 20) evaluated response persistence of task completion. Of these 20 experiments, only 35% evaluated the effect of computer tasks. Although task completion certainly involved experiments evaluating the effect of response persistence on computer related tasks (e.g., Kuroda, Cancado, & Podlesnik, 2016), additional tasks included spelling, math, stringing beads, and completing puzzles (Parry-Cruwys et al., 2011), as well as number and letter tracing (Vargo & Ringdahl, 2015). Therefore, future investigations might want to evaluate the effect of different disruptor variables on different types of tasks (e.g., academic tasks compared to computer tasks). For instance, does the presentation of a distractor (e.g., music or videos) affect academic tasks (e.g., Vargo & Ringdahl, 2015) differently than computer tasks (e.g., Dube et al., 2017)? In particular, future investigations might evaluate the effect of disruption on multistep or complex tasks (i.e., tasks requiring the individual to engage in covert verbal behavior) compared to one-step computer tasks requiring little to no covert verbal behavior.

Furthermore, Schieltz et al. (2017) described the impact of the number of instances target behavior contacts extinction. The authors stated that response extinction pairings correlated negatively with resurgence. Therefore, Schieltz et al. suggested future research evaluating pre- and posttreatment exposures to extinction and reinforcement to determine whether or not reinforcement to extinction ratios influence treatment durability. Likewise, researchers evaluating response persistence might consider evaluating the effect of number of exposures to disruptors on resistance to change.

Although a majority of the included studies involved different stimuli associated with different conditions (i.e., blue card associated with VI 30-s and red card associated with VI 12-s), only two included articles (Dube & McIlvane, 2002; Saini & Fisher, 2016) specifically evaluated the effect of these stimuli or stimulus variations. For example, Dube, McIlvane, Mazzitelli, and NcNamara (2003) evaluated the effect of stimuli with lower and high discrimination when challenged by a change in reinforcement schedules. Likewise, Saini and Fisher (2016) evaluated the effect of different stimuli salience on response persistence. Saini and Fisher stated BMT, "predicts that increasing the discriminability of the change from variable-interval to variable-time reinforcement should lead to faster reductions in responding" (p. 195). The current review only discovered the two aforementioned studies evaluating stimuli salience. Moreover, none of the studies evaluated the effect of verbal statements such as instructions on responding when challenged, despite experiments demonstrating response differences in the presence of verbal stimuli (Günther & Dougher, 2013).

Furthermore, although the purpose of this review was to synthesize the literature regarding changes in reinforcer conditions (i.e., response persistence), it should be noted that relapse paradigms, evaluating changes in treatment conditions (e.g., extinction; Podlesnik & Shahan, 2009) are also crucial to the field of applied behavior analysis. Furthermore, treatment relapse involves the reemergence of a response following intervention conditions previously resulting in extinguished behaviors (Pritchard, Hoerger, & Mace, 2014a). In particular, relapse involves at least three paradigms: reinstatement, resurgence, and renewal (Pritchard et al., 2014a). Reinstatement involves the delivery of the reinforcer maintaining rates of target behavior during baseline following extinction, which subsequently results in resumed rates of the target behavior (Pritchard et al., 2014a, b; Podlesnik & Shahan, 2009). Resurgence involves the reappearance of a previously extinguished behavior, extinguished through extinction and DRA, when the alternative behavior contacts extinction procedures (Doughty & Oken, 2008; Pritchard et al., 2014a). The third relapse paradigm, renewal, involves extinguishing a target behavior in a context different from the baseline context, and the target behavior reappears upon returning to the baseline context (Pritchard et al., 2014a).

Evaluating these three relapse paradigms through a framework of BMT might assist behavior analytic professionals in determining possible solutions to mitigate issues related to treatment relapse. Therefore, the authors hope to see future reviews evaluating experiments involving behavioral relapse paradigms (e.g., reinstatement, renewal, and resurgence) such as Pritchard, Hoerger, Mace, Penney, and Harris's, (2014b) study evaluating the effect of high compared to low rates of reinforcement during treatment on reinstatement. Pritchard et al. (2014b) discovered that although both rates of reinforcement produced similar results during treatment, responding was 2.6 times as high during reinstatement conditions in the context associated with higher rates of reinforcement. This finding is similar to the results identified in the current review indicating greater response persistence in contexts associated with richer schedules of reinforcement.

Limitations

As with any systematic literature review, publication bias might limit search results (e.g., Sham & Smith, 2014; Tincani & Travers, 2018). Sham and Smith (2014) indicated publication bias occurs when journals reject publications indicating null effects. For example, experiments indicating little to no difference in persistence following different reinforcement histories might not survive the peer-review process if the reason for the lack of difference was not explored. Furthermore, publication bias occurs when researchers do not submit datasets that do not report large differences across conditions (Tincani & Travers, 2018). In addition to publication bias, search terms might not result in a comprehensive list of experiments related to the current review. Therefore, the current review might not fully represent all of the BMT studies conducted with human participants.

As an additional limitation, the current review did not code the effect of repeated exposures to disruptors. For example, although not included in the review, Wacker et al.'s (2011) experiment evaluated persistence of treatment effects during long-term treatment. In this experiment, Wacker et al. also conceptualized maintenance as treatment durability during treatment challenges. For example, evaluating whether problem behavior relapses when presented with a disruptor such as a newly acquired FCR contacting extinction. The authors discovered decreased resistance to change over extended treatment periods, which implies longer treatment durations or repeated exposures to extinction might lead to more durable treatment outcomes. The current review did not code number of exposures to disruptors; therefore, this review does not provide information regarding the effect of continued exposure to disruptors on response persistence.

In summary, this review discovered several important factors regarding response persistence within the context of BMT as well as considerations for applied settings and future research. For instance, future research could focus investigations on the phenomena described in the preceding pages, including, but not limited to, variables affecting appropriate and inappropriate behavior and how those variables might affect generalization and maintenance of responding resulting in improved quality of life for individuals exhibiting behavioral concerns. Moreover, in light of recent events (i.e., the Covid-19 pandemic), perhaps researchers can evaluate variables influencing response persistence of behaviors related to public health behaviors such as mask wearing. After all, behavior analysis is only restricted by its principles and methods (Lerman, Iwata, & Hanley, 2013).

Compliance with Ethical Standards On behalf of all authors, the corresponding author states that there is no conflict of interest. Furthermore, as this is a literature review, this manuscript did not require informed consent.

Availability of Data and Materials Data sharing is not applicable to this article as no new data were created or analyzed.

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