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A review of investigations of operant renewal with human participants: Implications for theory and practice

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Operant renewal is the recurrence of a previously eliminated target behavior as a function of changing stimulus contexts. Renewal as a model of treatment relapse in humans suggests that a change in stimulus conditions or context is sufficient to produce relapse of a previously eliminated maladaptive behavior. The extent to which general findings from operant renewal studies involving nonhuman animal subjects are supported by relapse studies involving human participants is unknown. We conducted a systematic review of studies demonstrating or mitigating operant renewal in human participants in peer-reviewed studies found in *PsycINFO*, *ERIC*, *PubMed*, and *Scopus* between 1980 and 2019. We identified 12 studies involving 61 participants and 93 cases of operant renewal. We coded descriptive data on participant and study characteristics and calculated summary statistics. Results indicated that the renewal effect was a robust phenomenon, supported by demonstrations in both clinical and human-laboratory studies, and across a variety of variables and experimental preparations. However, there were relatively few studies involving human participants that attempted to reduce or eliminate renewal of clinically meaningful behavior. We discuss variables relevant for studying renewal in socially meaningful contexts, practical limitations of observing the renewal effect in real-world settings, implications for theoretical models of renewal, and identify barriers to methodology unique to human participants. We provide directions for future research related to implementing and translating nonhuman animal studies of renewal to applied settings.

Key words: humans, instrumental learning, operant renewal, recurrence, relapse, renewal

The environmental context in which operant learning occurs has long been considered an important variable in understanding behavioral mechanisms of relapse and related phenomena (Balsam, 1985; Bouton & Todd, 2014). In studies of operant learning, the term *context* has been used to describe a range of stimulus conditions that might come to influence behavior, even when contingencies remain constant across conditions (Podlesnik, Kelley, Jimenez-Gomez, & Bouton, 2017). For example, studies of operant conditioning involving human participants have used the term *context* to describe particular settings (e.g., home, clinic; Saini, Sullivan, Baxter, DeRosa, & Roane, 2018) and behavior-change agents (e.g., therapist, caregiver; Kelley, Jimenez-Gomez, Podlesnik, & Morgan, 2018) correlated with various reinforcement histories or contingencies. Whereas discriminative control refers to the evocative relation between antecedents and consequences, *contextual control* describes the greater array of environmental stimuli that modulate the ability of discriminative stimuli to control behavior (Trask, Thraikill, & Bouton, 2017). Context appears to play a fundamental role in operant response acquisition as well as operant inhibitory learning, which has allowed researchers to study the interaction between learning processes and context as it relates to *treatment relapse*, or the recurrence of previously eliminated behavior (Podlesnik & Kelley, 2015; Todd, Vurbic, & Bouton, 2014a; Vila, Romero, & Rosas, 2002; Wathen & Podlesnik, 2018).

Although it has been well established that contextual influences on behavior affect the degree of relapse in respondent conditioning (Bouton, 1993, 2002), as demonstrated in studies of phobias (Vervliet, Craske, & Hermans, 2013) among others, empirical investigations of contextual influences on relapse of operant behavior have only begun to emerge. Indeed, a new frontier of research concerning relapse has focused on how context affects behaviors that are controlled by their consequences (Bouton, Winterbauer, & Todd, 2012; Podlesnik & Kelley, 2015; Pritchard et al., 2016; Romero, Vila, & Rosas, 2003).

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Perhaps the most widely studied model of relapse attributable to contextual variables using nonhuman animals is *operant renewal* (e.g., Berry, Sweeney, & Odum, 2014; Bouton & Schepers, 2015; Bouton, Todd, Vurbic, & Winterbauer, 2011; Kelley, Liddon, Ribeiro, Greif, & Podlesnik, 2015; Nakajima, Tanaka, Urushihara, & Imada, 2000; Podlesnik & Shahan, 2009). In these studies, an organism is first trained to engage in a simple operant response (e.g., lever pressing) amongst a unique set of contextual stimuli (e.g., a distinct odor, delineated as "Context A"). Second, the target response is eliminated (typically using extinction) under a new set of unique contextual stimuli (e.g., a novel odor, delineated as "Context B"). Third, the organism is returned to the original training context (i.e., Context A), or a new context (e.g., a third odor, "Context C"), with the same contingencies in place as the prior response elimination phase. Recurrence of the target response upon reintroduction of the original context, or introducing a novel context, can result in what has been termed ABA or ABC renewal, respectively, with treatment relapse occurring despite previous response elimination in Context B. In some renewal studies, the response is trained and eliminated in the same context (i.e., Context A) prior to exposing the organism to a new set of unique contextual stimuli (i.e., Context B), which can result in AAB renewal.

The relapse of operant behavior as a function of contextual variables, like those described in studies of renewal, may be of particular importance in clinical applications of behavior analysis. This is largely because behavioral treatments (a) heavily emphasize shaping behavior through response–consequence contingencies (i.e., operant conditioning; Kazdin, 2012; Skinner, 1988), (b) are often conducted in settings outside of the individual's typical environment (e.g., specialized clinics or treatment facilities; Borckardt et al., 2008; Petry, 2000), and (c) are introduced initially by clinicians or therapists as opposed to natural behavior-change agents (e.g., caregivers; Bernstein, 1982; Neef, 1995; Wood, Luiselli, & Harchik, 2007). An analysis of the contextual factors involved in treating behavior disorders in humans may provide some guidance as to why treatment gains are often difficult to sustain over long periods of time (Bouton, 2014).

Renewal as a model of treatment relapse in humans suggests that a change in stimulus conditions or context is sufficient to produce relapse of a previously eliminated maladaptive behavior (Podlesnik et al., 2017). The implication for treatment generalization from nonhuman animal research is that maladaptive behavior learned in one context (e.g., a child's aggression toward classroom teachers at school to gain adult attention) and eliminated through intervention in a treatment context (e.g., behavioral treatment with trained therapists in a clinic setting) could relapse upon implementation of the treatment in the original context (e.g., school) or a novel context (e.g., with caregivers at home). It has been suggested that renewal of maladaptive behavior can occur despite individuals making dramatic changes in lifestyle such as changing cities, friends, and work or school (Pierce & Cheney, 2013).

Podlesnik et al. (2017) suggested that relapse of maladaptive behavior (e.g., destructive behavior in children with intellectual or developmental disabilities) following treatment could be due to renewal because the individual is exposed to contexts correlated with reinforcement of the maladaptive response (similar to the "training context" described in nonhuman animal studies) or because novel contexts are often targeted for treatment generalization (similar to Context C in ABC renewal). Although there have been demonstrations of generalization failures across contexts in clinical behavior analysis consistent with the operant renewal model (e.g., Saini et al., 2018), the expanse of this phenomenon is unknown, making it difficult to draw firm conclusions about the relapse of maladaptive behavior due to contextual variables. Many of the claims made in prior research with respect to renewal of human behavior have been extrapolated from laboratory research with nonhuman animals. No studies have synthesized the extant literature on operant renewal with humans in clinical settings, or even with humans in laboratory settings.

One limitation of prior discussion articles and reviews of operant renewal is that studies involving human participants have always been combined with studies of nonhuman animals, making it difficult to identify contextual variables that are uniquely human, and relevant when understanding relapse of maladaptive behavior in clinical situations. Moreover, the

extent to which renewal mitigation strategies described in nonhuman animal studies could be implemented or translated to applied settings is unclear given the unique barriers that exist in real-world settings (e.g., the dynamic nature of changing contexts in clinical settings; Sullivan, Saini, & Roane, 2018). Few review papers have discussed the unique barriers to studying and mitigating renewal in real-world settings or how those barriers could be overcome. Lastly, several review articles have made arguments about variables contributing to renewal in real-world settings; however, it is unknown to what extent those arguments are supported by studies involving human participants.

The purpose of this review was to synthesize the literature on operant renewal with humans in order to (a) detect trends and differences across studies, (b) identify variables relevant for studying renewal in socially meaningful contexts, (c) identify barriers to methodology unique to human participants, (d) elucidate implications for theoretical models of renewal based on studies involving human participants, and (e) inform areas of future research on relapse.

Method

Search Strategy and Study Identification

In conducting this review, we followed the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement (Moher, Liberati, Tetzlaff, & Altman, 2009; Moher et al., 2015). We searched the databases of *PsycINFO*, *ERIC*, *PubMed*, and *Scopus* to identify peer-reviewed studies published in journals written in English between 1980 and 2019. We used the keyword *renewal* during our search. We also examined the references of obtained articles to identify studies we did not identify in the initial search. In addition to this search strategy, we contacted the editors of the *Journal of the Experimental Analysis of Behavior* and the *Journal of Applied Behavior Analysis* to identify articles have been accepted for publication but have not yet appeared in an issue of either journal.

We included studies that met the following criteria: (a) the study enrolled human participants, (b) the study used direct observation of the primary dependent variable(s), collected in vivo or video recorded for subsequent scoring, under naturalistic or analogue conditions, and (c) the study explicitly described studying operant renewal or variables affecting operant renewal. In addition to studies that evaluated operant renewal as a singular relapse phenomenon, we also included preparations that combined contextual changes with other variables commonly associated with relapse (e.g., the resurgence of maladaptive behavior as a result of decrements in reinforcement for a newly taught alternative response). We included these studies because combined relapse arrangements may better simulate what occurs in practice when multiple environmental events interact during relapse (e.g., Mitteer, Greer, Fisher, Briggs, & Wacker, 2018). We excluded studies that (a) examined operant renewal using nonhuman animal subjects, (b) examined renewal in a respondent conditioning paradigm with humans, (c) described simple failures of generalization across environments or contexts (e.g., Schindler & Horner, 2005), (d) did not report or display data at the individual level, and (e) were reviews, meta-analyses, book chapters, or dissertations.

The authors examined each study obtained using the initial search criteria to determine whether each study met the inclusion criteria outlined above. We calculated interrater agreement by dividing the number of agreements (i.e., both raters agreed the study should be included or excluded) by the number of agreements plus disagreements and converting the resulting proportion to a percentage. Raters agreed on 100% of studies for inclusion.

Variables Coded, Data Extraction, and Interrater Agreement

We categorized studies meeting the initial inclusion criteria as either demonstrations of operant renewal with humans or attempts to mitigate operant renewal with humans. Studies were categorized as demonstrations if the study's purpose was to validate or illustrate the renewal effect with no aim to prevent renewal. Studies were categorized as mitigation studies if the study's purpose was to prevent or minimize the renewal effect from occurring.

Studies were also categorized as clinical investigations or human-laboratory preparations. Clinical investigations were studies that examined operant renewal using socially significant dependent variables (e.g., dangerous or destructive behavior) and across clinically

meaningful contexts (e.g., home, school). Human-laboratory preparations were those studies that investigated renewal in the absence of socially significant dependent variables (e.g., depositing balls in a box) or across contexts that were not socially meaningful (e.g., different colored t-shirts worn by experimenters). Participant characteristics related to neurodevelopmental status did not affect whether a study was categorized as a clinical investigation or human-laboratory preparation.

Studies were categorized according to the type of renewal studied. Studies were categorized as ABA, ABC, or AAB renewal. We determined type of renewal based on the contextual and experimental design described in each study.

We extracted descriptive variables from each study and coded them using a standardized electronic checklist and coding system. We extracted data on participant characteristics (age, gender, neurodevelopmental status), dependent variable(s) studied (e.g., destructive behavior, button press), purpose of renewal investigation (demonstration, mitigation), type of preparation (clinical, human laboratory), type of renewal (ABA, ABC, AAB), type of reinforcers used (e.g., food, points), reinforcement schedules across contexts (e.g., fixed ratio [FR], extinction), and contextual stimuli (i.e., how contexts were defined by the authors of each study). If studies examined a renewal-mitigation strategy, we further extracted descriptive data on how the strategy was employed (e.g., fading stimuli from Context B to Context C).

The authors independently examined 100% of the studies that met inclusion. Raters independently coded data extracted during the review process. We assessed item-by-item interrater agreement by comparing the study characteristics each rater recorded. We calculated interrater agreement by dividing the number of rater agreements by the number of rater agreements plus rater disagreements and converting the resulting proportion to a percentage for each study. We then calculated a mean of the mean interrater agreement coefficients for each study, resulting in a mean interrater agreement of 99.5% across studies. Disagreements were discussed and resolved prior to formal data analysis by the authors.

Data Analysis

We collected data on individual cases of operant renewal within and across studies. We defined *case* as a single demonstration or investigation of renewal in a single-subject design across an explicitly defined set of contextual stimuli as described by the authors of each study. Therefore, if a study examined the effects of different types of renewal (e.g., ABA, ABC) for one participant's target behavior, we considered and analyzed this as multiple cases. We also delineated cases by different reinforcement schedules. For example, if a study examined renewal with two distinct reinforcement schedules, we considered and analyzed this as two cases. Cases in which operant renewal was studied in combination with resurgence were described as *combined relapse*. During data analysis, we used the total number of cases as the denominator to protect against artificially inflating overall percentages and means.

We extracted single-case data from the figures of each publication to determine the rate or percentage of the target behavior during the last session of the response elimination phase (i.e., Phase 2) and during each session of the renewal test (i.e., each Phase-3 session) to determine whether renewal occurred. Renewal was indicated when a relative increase in target behavior responding was observed during the first session of the renewal test compared to the final session of the response elimination phase. This objective method of determining a renewal effect is consistent with that used in previous research (Berry et al., 2014; Kelley et al., 2015; Liddon, Kelley, Rey, Liggett, & Ribeiro, 2018; Nakajima et al., 2000; Sweeney & Shahan, 2015). We also assessed the correspondence of renewal prevalence when using this definition compared to (a) when a relative increase in target behavior responding was observed during *any* session of the renewal test compared to the final session of the response elimination phase (e.g., Ibañez, Piazza, & Peterson, 2019) and (b) the conclusions of whether a renewal effect was observed based on the interpretation of the authors of each respective study.

Results

We identified 65,323 articles during the initial search of databases and journal archives. Of these, 65,309 articles were excluded without detailed text review because they were duplicates or because the titles, abstract, or

keywords did not meet the initial inclusion criteria. The remaining 14 articles met criteria for full-text review. The detailed review resulted in an additional four articles being removed because they were studies of respondent conditioning (one study) or did not display individual participant data (three studies). This resulted in the identification of 10 articles. The journal editors did not identify additional articles; however, the second author identified and requested two additional "in press" studies that were experiments from an affiliated institution at the time this review was conducted. This resulted in a total of 12 studies included in the review. Within the 12 studies, there were 61 participants and 93 cases of operant renewal with human participants identified.

We listed studies chronologically and then alphabetically (by the first author's last name) within each publication year. We then assigned case numbers according to the order in which authors presented participant data. For example, the earliest identified articles were published in 2015 (i.e., Alessandri, Lattal, & Cançado, 2015; Kelley et al., 2015), therefore, we assigned the first case number to the first human data set presented in Alessandri et al. (2015; i.e., P4).

Participant Characteristics

Table 1 displays participant characteristics. The majority of cases (63 of 93; 68%) assessed renewal with children. Of the 42 cases in which authors reported each participant's age, children were 2–9 (M = 4.8) years old and adults were 18–43 (M = 30.5) years old. When authors specified participant gender, almost all were described as male (33 of 37; 89%). Authors indicated that the participants had a developmental or intellectual disability in greater than half of cases (56 of 93; 60%). Participants engaged in a variety of different responses, with most (62 of 93; 67%) being arbitrarily selected or not socially significant (e.g., pressing a button on a computer screen, depositing a ball in an object-permanence box). Studies also evaluated clinically relevant behavior (e.g., problem behavior, compliance) in 24% of cases (22 of 93) and incorporated preacademic skills (e.g., writing, matching) occasionally (9 of 93; 14%).

Authors generally programmed a social-positive reinforcer (72 of 93; 77%) for participant responding. Tangibles, edibles, or attention were used in 28, 24, and 2 cases, respectively, and points (or points exchangeable for money) were used in 24 cases (25%). Tangibles, edibles, or attention were used with children exclusively, and points were used as a reinforcer with adults exclusively. The remainder of cases programmed social-negative reinforcement (e.g., escape from demands; 14 of 93; 15%) or a combination of social-positive and social-negative reinforcement (e.g., escape to attention, 7 of 93; 8%).

Study Characteristics

Table 2 displays study characteristics and variables assessed during renewal investigations. Authors evaluated renewal in human-laboratory arrangements most often (71 of 93; 76%) compared to in clinically meaningful arrangements or contexts (22 of 93; 24%). Similarly, studies tended to program arbitrary contextual stimuli (73 of 93; 78%), using colored stimuli (e.g., colored t-shirts or computer backgrounds) in 67 cases and the presence of lights or tones in six cases. Authors programmed more naturalistic contextual stimuli in the remaining cases (20 of 93; 22%), with different implementers (e.g., therapist, caregiver), unique settings (e.g., clinic, home), or different implementers in unique settings (e.g., therapist in clinic, caregiver in home) in four, four, and 12 cases, respectively.

Most cases evaluated ABA renewal (74 of 93; 80%), though some authors assessed renewal upon introduction of a novel context using AAB and ABC renewal preparations in six and four cases, respectively. Nine cases involved what Sullivan et al. (2018) described as ACA renewal in which the response-elimination phase alternated between extinction in a unique context and reinforcement of target responding in the baseline context. Sullivan et al. used this arrangement to simulate caregivers reinforcing problem behavior outside of clinical appointments prior to the treatment transferring to the caregivers in the baseline context.

In general, studies used the standard three-phase arrangement (e.g., reinforcement, extinction, extinction) in which researchers reinforced target responding during baseline according to a variable-ratio (37 cases; 40%), fixed-ratio (30 cases; 32%), or variable-interval

Table 1

Summary of participant characteristics, target responses, and programmed reinforcers

Case	Article	Participant	Age	Gender	Diagnosis	Responses	Reinforcer
1	Alessandri et al. (2015)	P4	-	M	-	Force-cell push	Escape
2	Alessandri et al. (2015)	P5	-	M	-	Force-cell push	Escape
3	Alessandri et al. (2015)	P6	-	M	-	Force-cell push	Escape
4	Kelley et al. (2015)	Drew	4	M	ASD	Matching	Edible
5	Kelley et al. (2015)	John	9	M	ASD	Tracing	Edible
6	Pritchard et al. (2016)	Participant	18	M	Severe ID	PB, FCR	Attention
7	Pritchard et al. (2016)	Participant	18	M	Severe ID	PB, FCR	Attention
8	Cohenour et al. (2018)	Emmett	5	M	ASD	Lever pull	Edible
9	Cohenour et al. (2018)	Emmett	5	M	ASD	Lever pull	Edible
10	Cohenour et al. (2018)	Bastian	7	M	ASD	Lever pull	Edible
11	Cohenour et al. (2018)	Bastian	7	M	ASD	Lever pull	Edible
12	Cohenour et al. (2018)	Will	9	M	ASD	Lever pull	Edible
13	Cohenour et al. (2018)	Will	9	M	ASD	Lever pull	Edible
14	Kelley et al. (2018)	Drew	3	M	ASD	PB, compliance	Escape
15	Kelley et al. (2018)	Drew	3	M	ASD	PB, compliance	Escape
16	Kelley et al. (2018)	Stephen	5	M	ASD	IMB	Escape
17	Kelley et al. (2018)	Stephen	5	M	ASD	IMB	Escape
18	Kelley et al. (2018)	Jules	5	M	ASD	IMB	Escape
19	Kelley et al. (2018)	Jules	5	M	ASD	IMB	Escape
20	Liddon et al. (2018)	Cole	3	-	ASD	Matching	Edible
21	Liddon et al. (2018)	Vaughn	3	-	ASD	Depositing blocks	Tangible
22	Liddon et al. (2018)	Bella	3	-	ASD	Writing	Tangible
23	Liddon et al. (2018)	Dermot	3	-	ASD	Depositing blocks	Edible
24	Liddon et al. (2018)	Liam	3	-	ASD	Matching	Edible
25	Liddon et al. (2018)	Liam	3	-	ASD	Matching	Edible
26	Liddon et al. (2018)	Preston	4	-	ASD	Sorting	Edible
27	Liddon et al. (2018)	Preston	4	-	ASD	Sorting	Edible
28	*Mitteer et al. (*2018*)*	Michelle	26	F	-	UCB, DCB	Escape
29	*Mitteer et al. (*2018*)*	Debbie	38	F	-	UCB, DCB	Escape
30	*Mitteer et al. (*2018*)*	Nicole	43	F	-	UCB, DCB	Escape
31	*Mitteer et al. (*2018*)*	Chandler	40	M	-	UCB, DCB	Escape
32	Saini et al. (2018)	Sarah	8	F	ASD, DS	PB, FCR	Escape, tangible
33	Saini et al. (2018)	Harry	8	M	ASD	PB, FCR	Tangible
34	Saini et al. (2018)	Zack	8	M	ASD	PB, FCR	Escape, tangible
35	Saini et al. (2018)	Mario	7	M	ASD	PB, FCR	Tangible
36	Sullivan et al. (2018)	P1	-	-	-	Key press	Points
37	Sullivan et al. (2018)	P1	-	-	-	Key press	Points
38	Sullivan et al. (2018)	P2	-	-	-	Key press	Points
39	Sullivan et al. (2018)	P2	-	-	-	Key press	Points
40	Sullivan et al. (2018)	P3	-	-	-	Key press	Points
41	Sullivan et al. (2018)	P3	-	-	-	Key press	Points
42	Sullivan et al. (2018)	P4	-	-	-	Key press	Points
43	Sullivan et al. (2018)	P4	-	-	-	Key press	Points
44	Sullivan et al. (2018)	P5	-	-	-	Key press	Points
45	Sullivan et al. (2018)	P5	-	-	-	Key press	Points
46	Sullivan et al. (2018)	P6	-	-	-	Key press	Points
47	Sullivan et al. (2018)	P6	-	-	-	Key press	Points
48	Sullivan et al. (2018)	P7	-	-	-	Key press	Points
49	Sullivan et al. (2018)	P7	-	-	-	Key press	Points
50	Sullivan et al. (2018)	P8	-	-	-	Key press	Points
51	Sullivan et al. (2018)	P8	-	-	-	Key press	Points
52	Sullivan et al. (2018)	P9	-	-	-	Key press	Points
53	Sullivan et al. (2018)	P9	-	-	-	Key press	Points
54	*Podlesnik et al. (*2019*)*	S1	-	-	-	Mouse clicks	Points for money
55	*Podlesnik et al. (*2019*)*	S2	-	-	-	Mouse clicks	Points for money

Table 1

Continued

Case	Article	Participant	Age	Gender	Diagnosis	Responses	Reinforcer
56	*Podlesnik et al. (*2019*)*	S3	-	-	-	Mouse clicks	Points for money
57	*Podlesnik et al. (*2019*)*	S4	-	-	-	Mouse clicks	Points for money
58	*Podlesnik et al. (*2019*)*	S5	-	-	-	Mouse clicks	Points for money
59	*Podlesnik et al. (*2019*)*	S6	-	-	-	Mouse clicks	Points for money
60	*Podlesnik et al. (*2019*)*	Ned	4	M	ASD	Button presses	Edible
61	*Podlesnik et al. (*2019*)*	Walt	4	M	ASD	Button presses	Edible
62	*Podlesnik et al. (*2019*)*	Marv	6	M	ASD	Button presses	Edible
63	*Podlesnik et al. (*2019*)*	Hank	3	M	ASD	Button presses	Edible
64	Ibañez et al. (2019)	Carlos	3	M	ASD	IMB	Escape, attention
65	Ibañez et al. (2019)	Carlos	3	M	ASD	IMB	Escape, attention
66	Ibañez et al. (2019)	Fernando	3	M	None	IMB	Escape, attention
67	Ibañez et al. (2019)	Pierre	4	M	None	IMB	Escape, attention
68	Ibañez et al. (2019)	Lorenzo	2	M	DD	IMB	Escape, attention, tangible
69	Ibañez et al. (2019)	Lorenzo	2	M	DD	IMB	Escape
70	Kimball et al. (2020)	Angel	-	-	None	Ball deposits	Tangible
71	Kimball et al. (2020)	Angel	-	-	None	Ball deposits	Tangible
72	Kimball et al. (2020)	James	-	-	ASD	Ball deposits	Tangible
73	Kimball et al. (2020)	James	-	-	ASD	Ball deposits	Tangible
74	Kimball et al. (2020)	Robert	-	-	ASD	Ball deposits	Tangible
75	Kimball et al. (2020)	Robert	-	-	ASD	Ball deposits	Tangible
76	Kimball et al. (2020)	David	-	-	ASD	Ball deposits	Tangible
77	Kimball et al. (2020)	David	-	-	ASD	Ball deposits	Tangible
78	Kimball et al. (2020)	Julian	-	-	ASD	Ball deposits	Tangible
79	Kimball et al. (2020)	Julian	-	-	ASD	Ball deposits	Tangible
80	Kimball et al. (2020)	Eric	-	-	ASD	Ball deposits	Tangible
81	Kimball et al. (2020)	Eric	-	-	ASD	Ball deposits	Tangible
82	Kimball et al. (2020)	Trevor	-	-	ASD	Ball deposits	Tangible
83	Kimball et al. (2020)	Trevor	-	-	ASD	Ball deposits	Tangible
84	Kimball et al. (2020)	Peter	-	-	ASD	Ball deposits	Tangible
85	Kimball et al. (2020)	Peter	-	-	ASD	Ball deposits	Tangible
86	Kimball et al. (2020)	Jean	-	-	ASD	Ball deposits	Tangible
87	Kimball et al. (2020)	Jean	-	-	ASD	Ball deposits	Tangible
88	Kimball et al. (2020)	Teon	-	-	ASD	Ball deposits	Tangible
89	Kimball et al. (2020)	Teon	-	-	ASD	Ball deposits	Tangible
90	Kimball et al. (2020)	Magnus	-	-	ASD	Ball deposits	Tangible
91	Kimball et al. (2020)	Magnus	-	-	ASD	Ball deposits	Tangible
92	Kimball et al. (2020)	Alison	-	-	None	Ball deposits	Tangible
93	Kimball et al. (2020)	Alison	-	-	None	Ball deposits	Tangible

Note: Italics in Column 2 indicate that the study used a design that combined renewal with another relapse phenomenon. A dash (-) indicates that the authors did not report the information. Alessandri et al. (2015) reported that undergraduates participated. Sullivan et al. (2018) reported that seven women and two men ages 18-30 (M = 21.4) years old participated. Podlesnik et al. (2019) reported that adults ages 19-21 years old participated. Kimball et al. (2020) indicated that children were 2-18 (M = 4.25) years old. M = male. F = female. ASD = autism spectrum disorder. ID = intellectual disability. DS = Down syndrome. DD = developmental delays. PB = problem behavior. FCR = functional communication response. IMB = inappropriate mealtime behavior. UCB = undesirable caregiver behavior. DCB = desirable caregiver behavior.

(26 cases; 28%) schedule. Most of the cases (61 of 93; 66%) evaluated renewal by programming extinction in the response elimination phase and test phase. However, authors also assessed renewal following DRA with extinction in which reinforcement of the alternative response continued during the renewal test (18 of 93; 19%) or discontinued during the combined-relapse test (14 of 93; 15%). When authors programmed reinforcement for an alternative response, they used a fixed-ratio-1 schedule (14 of 32; 43%), a variable-ratio-2 schedule (12 of 32; 38%), or a variable-interval-20-s schedule (6 of 32; 19%).

Figure 1 displays the prevalence of renewal based on our objective visual-inspection criteria (i.e., an increase in target responding during the first session of Phase 3 relative to the last session of Phase 2). Renewal was pervasive across study types, experimental design, contextual stimuli, and participant characteristics, occurring in 83% (77 of 93) of cases (Fig. 1, first black bar). When removing the three cases in Kelley et al. (2018) involving a mitigation technique or the nine cases in Kimball, Greer, Randall, and Briggs (2020) aimed to demonstrate less renewal when alternative-response materials are absent during baseline, the prevalence of operant renewal increases to 89% (72 of 81; Fig. 1, first gray bar). Of these cases, relapse occurred more often during renewal arrangements (61 of 67; 91%) than combined-relapse arrangements (11 of 14; 79%).

It is possible that this difference in observed renewal between standard three-phase renewal preparations and combined-relapse preparations is due to delayed increases in target responding during Phase 3, which would not be detected by our criteria (e.g., observed in two of the 10 cases—Cases 56 and 63—from Podlesnik et al., 2019). When we expanded our criteria by examining relative levels of responding in the last session of the elimination phase to levels of the target behavior in any Phase-3 session, the prevalence of renewal increased to 88% of all cases and 95% of nonmitigation cases (Fig. 1, second set of bars).

The conclusions of each article's authors regarding the occurrence of renewal were compared to both our original and modified criteria and results were similar to our objective definitions, with 83% of all cases demonstrating a renewal effect and 93% of nonmitigation cases displaying a renewal effect (Fig. 1, third set of bars). Authors tended to vary in their categorization of delayed effects as renewal (e.g., Liddon et al., 2018; Podlesnik et al., 2019). Additionally, some authors (e.g., Kimball et al., 2020; Saini et al., 2018) did not describe modest increases in target behavior as renewal despite our definition detecting an increase in target responding from the last session of Phase 2 compared to the first session of Phase 3.

Four cases (9, 26, 29, 80) that failed to demonstrate renewal outside of mitigation cases varied in design (two ABA, one ABC, one AAB) and preparation (three human-laboratory cases with arbitrary contextual stimuli, one clinical case with naturalistic contextual stimuli). We could not identify any consistent variables correlated with these cases that might have resulted in a lack of relapse. The participants in Cases 9 and 26 displayed renewal with other contextual changes (see Cases 8 and 27, respectively), indicating differential sensitivity to specific contextual stimuli. There were no notable variables that may have contributed to the lack of renewal for Case 80. For the only adult who did not display relapse (Case 29), she noted to the experimenters that she received additional behavioral training outside of the study (i.e., behavioral skills training in how to implement differential attention with her child) that may have resulted in her lack of undesirable caregiver behavior (i.e., providing attention following confederate destructive behavior) during the combined-relapse test.

Most of the cases involved demonstrations of renewal. Only Kelley et al. (2018) stated explicitly that they attempted to mitigate renewal using context fading and did so successfully in all three cases. Although Kimball et al. (2020) did not intend to evaluate a mitigation strategy per se, removal of the alternative-response materials during baseline resulted in renewal in only two of nine cases. This would be similar to behavior analysts introducing the communication card into the baseline context only after pairing the card with functional communication training in the clinic, which may serve as a treatment signal to mitigate renewal (Saini et al., 2018). Taken together, most cases demonstrated how to occasion renewal, but few cases illustrated how to reduce it with human participants, and those mitigation cases occurred in ABA renewal preparations only.

Table 2

Summary of study characteristics

Case	Article	Study Type	Contextual Stimuli	Design	Reinforcement Schedule	Relapse
1	Alessandri et al. (2015)	Laboratory	Colors	ABA	VR23, EXT, EXT	Y
2	Alessandri et al. (2015)	Laboratory	Colors	ABA	VR23, EXT, EXT	Y
3	Alessandri et al. (2015)	Laboratory	Colors	ABA	VR23, EXT, EXT	Y
4	Kelley et al. (2015)	Laboratory	Colors	ABA	FR1, EXT, EXT	Y
5	Kelley et al. (2015)	Laboratory	Colors	ABA	FR1, EXT, EXT	Y
6	Pritchard et al. (2016)	Clinical Clinical	Colors	ABA	VI60s, VI/VT30s, EXT, EXT	Y
7	Pritchard et al. (2016)	Clinical	Colors	ABA	VI60s, VI/VT120s, EXT, EXT	Y
8	Cohenour et al. (2018)	Laboratory	Presence of light	AAB	FR1→VR4, EXT, EXT	Y
9	Cohenour et al. (2018)	Laboratory	Presence of buzzer	AAB	FR1→VR4, EXT, EXT	N
10	Cohenour et al. (2018)	Laboratory	Presence of buzzer	AAB	FR1→VR4, EXT, EXT	Y
11	Cohenour et al. (2018)	Laboratory	Presence of light	AAB	FR1→VR4, EXT, EXT	Y
12	Cohenour et al. (2018)	Laboratory	Presence of buzzer	AAB	FR1→VR4, EXT, EXT	Y
13	Cohenour et al. (2018)	Laboratory	Presence of light	AAB	FR1→VR4, EXT, EXT	Y
14	Kelley et al. (2018)	Clinical	Settings, implementers	ABA	FR1, EXT/FR1, EXT/FR1	Y
15	Kelley et al. (2018)	Clinical	Settings, implementers	ABA	FR1, EXT/FR1, EXT/FR1	**N**
16	Kelley et al. (2018)	Clinical	Implementers	ABA	FR1, EXT, EXT	N
17	Kelley et al. (2018)	Clinical	Implementers	ABA	FR1, EXT, EXT	**N**
18	Kelley et al. (2018)	Clinical	Implementers	ABA	FR1, EXT, EXT	Y
19	Kelley et al. (2018)	Clinical	Implementers	ABA	FR1, EXT, EXT	**N**
20	Liddon et al. (2018)	Laboratory	Colors	ABA	FR1, EXT, EXT	Y
21	Liddon et al. (2018)	Laboratory	Colors	ABA	FR1, EXT, EXT	Y
22	Liddon et al. (2018)	Laboratory	Colors	ABC	FR1, EXT, EXT	Y
23	Liddon et al. (2018)	Laboratory	Colors	ABC	FR1, EXT, EXT	N
24	Liddon et al. (2018)	Laboratory	Colors	ABC	FR1, EXT, EXT	Y
25	Liddon et al. (2018)	Laboratory	Colors	ABA	FR1, EXT, EXT	Y
26	Liddon et al. (2018)	Laboratory	Colors	ABC	FR1, EXT, EXT	N
27	Liddon et al. (2018)	Laboratory	Colors	ABA	FR1, EXT, EXT	Y
28	*Mitteer et al. (*2018*)*	Clinical	Settings	ABA	FR1, FR1/FR1, EXT/EXT	Y
29	*Mitteer et al. (*2018*)*	Clinical	Settings	ABA	FR1, FR1/FR1, EXT/EXT	N
30	*Mitteer et al. (*2018*)*	Clinical	Settings	ABA	FR1, FR1/FR1, EXT/EXT	Y
31	*Mitteer et al. (*2018*)*	Clinical	Settings	ABA	FR1, FR1/FR1, EXT/EXT	Y
32	Saini et al. (2018)	Clinical	Settings, implementers	ABA	FR1/EXT, EXT/FR1, EXT/FR1	Y
33	Saini et al. (2018)	Clinical	Settings, implementers	ABA	FR1/EXT, EXT/FR1, EXT/FR1	Y
34	Saini et al. (2018)	Clinical	Settings, implementers	ABA	FR1/EXT, EXT/FR1, EXT/FR1	Y
35	Saini et al. (2018)	Clinical	Settings, implementers	ABA	FR1/EXT, EXT/FR1, EXT/FR1	Y
36	Sullivan et al. (2018)	Laboratory	Colors	ABA	VI10s, EXT, EXT	Y
37	Sullivan et al. (2018)	Laboratory	Colors	ACA	VI10s, EXT or VI10s, EXT	Y
38	Sullivan et al. (2018)	Laboratory	Colors	ABA	VI10s, EXT, EXT	Y
39	Sullivan et al. (2018)	Laboratory	Colors	ACA	VI10s, EXT or VI10s, EXT	Y
40	Sullivan et al. (2018)	Laboratory	Colors	ABA	VI10s, EXT, EXT	Y
41	Sullivan et al. (2018)	Laboratory	Colors	ACA	VI10s, EXT or VI10s, EXT	Y
42	Sullivan et al. (2018)	Laboratory	Colors	ABA	VI10s, EXT, EXT	Y
43	Sullivan et al. (2018)	Laboratory	Colors	ACA	VI10s, EXT or VI10s, EXT	Y
44	Sullivan et al. (2018)	Laboratory	Colors	ABA	VI10s, EXT, EXT	Y
45	Sullivan et al. (2018)	Laboratory	Colors	ACA	VI10s, EXT or VI10s, EXT	Y
46	Sullivan et al. (2018)	Laboratory	Colors	ABA	VI10s, EXT, EXT	Y
47	Sullivan et al. (2018)	Laboratory	Colors	ACA	VI10s, EXT or VI10s, EXT	Y
48	Sullivan et al. (2018)	Laboratory	Colors	ABA	VI10s, EXT, EXT	Y
49	Sullivan et al. (2018)	Laboratory	Colors	ACA	VI10s, EXT or VI10s, EXT	Y
50	Sullivan et al. (2018)	Laboratory	Colors	ABA	VI10s, EXT, EXT	Y
51	Sullivan et al. (2018)	Laboratory	Colors	ACA	VI10s, EXT or VI10s, EXT	Y
52	Sullivan et al. (2018)	Laboratory	Colors	ABA	VI10s, EXT, EXT	Y
53	Sullivan et al. (2018)	Laboratory	Colors	ACA	VI10s, EXT or VI10s, EXT	Y
54	*Podlesnik et al. (*2019*)*	Laboratory	Colors	ABA	VI20s, EXT/VI20s, EXT/EXT	Y

Table 2
Continued

Case	Article	Study Type	Contextual Stimuli	Design	Reinforcement Schedule	Relapse
55	*Podlesnik et al. (*2019*)*	Laboratory	Colors	ABA	VI20s, EXT/VI20s, EXT/EXT	Y
56	*Podlesnik et al. (*2019*)*	Laboratory	Colors	ABA	VI20s, EXT/VI20s, EXT/EXT	N
57	*Podlesnik et al. (*2019*)*	Laboratory	Colors	ABA	VI20s, EXT/VI20s, EXT/EXT	Y
58	*Podlesnik et al. (*2019*)*	Laboratory	Colors	ABA	VI20s, EXT/VI20s, EXT/EXT	Y
59	*Podlesnik et al. (*2019*)*	Laboratory	Colors	ABA	VI20s, EXT/VI20s, EXT/EXT	Y
60	*Podlesnik et al. (*2019*)*	Laboratory	Colors	ABA	VR2, EXT/FR1, EXT/EXT	Y
61	*Podlesnik et al. (*2019*)*	Laboratory	Colors	ABA	VR3, EXT/FR1, EXT/EXT	Y
62	*Podlesnik et al. (*2019*)*	Laboratory	Colors	ABA	VR3, EXT/FR1, EXT/EXT	Y
63	*Podlesnik et al. (*2019*)*	Laboratory	Colors	ABA	VR3, EXT/FR1, EXT/EXT	N
64	Ibañez et al. (2019)	Clinical	Settings, implementers	ABA	FR1, EXT, EXT	Y
65	Ibañez et al. (2019)	Clinical	Settings, implementers	ABA	FR1, EXT, EXT	Y
66	Ibañez et al. (2019)	Clinical	Settings, implementers	ABA	FR1, EXT, EXT	N
67	Ibañez et al. (2019)	Clinical	Settings, implementers	ABA	FR1, EXT, EXT	Y
68	Ibañez et al. (2019)	Clinical	Settings, implementers	ABA	FR1, EXT, EXT	Y
69	Ibañez et al. (2019)	Clinical	Settings, implementers	ABA	FR1, EXT, EXT	Y
70	Kimball et al. (2020)	Laboratory	Colors	ABA	VR2, EXT/VR2, EXT/VR2	N
71	Kimball et al. (2020)	Laboratory	Colors	ABA	VR2, EXT, EXT	Y
72	Kimball et al. (2020)	Laboratory	Colors	ABA	VR2, EXT, EXT	Y
73	Kimball et al. (2020)	Laboratory	Colors	ABA	VR2, EXT/VR2, EXT/VR2	Y
74	Kimball et al. (2020)	Laboratory	Colors	ABA	VR2, EXT/VR2, EXT/VR2	N
75	Kimball et al. (2020)	Laboratory	Colors	ABA	VR2, EXT, EXT	Y
76	Kimball et al. (2020)	Laboratory	Colors	ABA	VR2, EXT, EXT	Y
77	Kimball et al. (2020)	Laboratory	Colors	ABA	VR2, EXT/VR2, EXT/VR2	Y
78	Kimball et al. (2020)	Laboratory	Colors	ABA	VR2, EXT/VR2, EXT/VR2	Y
79	Kimball et al. (2020)	Laboratory	Colors	ABA	VR2, EXT, EXT	Y
80	Kimball et al. (2020)	Laboratory	Colors	ABA	VR2, EXT, EXT	N
81	Kimball et al. (2020)	Laboratory	Colors	ABA	VR2, EXT/VR2, EXT/VR2	N
82	Kimball et al. (2020)	Laboratory	Colors	ABA	VR2/EXT, EXT/EXT, EXT/EXT	Y
83	Kimball et al. (2020)	Laboratory	Colors	ABA	VR2/EXT, EXT/VR2, EXT/VR2	Y
84	Kimball et al. (2020)	Laboratory	Colors	ABA	VR2/EXT, EXT/VR2, EXT/VR2	Y
85	Kimball et al. (2020)	Laboratory	Colors	ABA	VR2/EXT, EXT/EXT, EXT/EXT	Y
86	Kimball et al. (2020)	Laboratory	Colors	ABA	VR2/EXT, EXT/EXT, EXT/EXT	Y
87	Kimball et al. (2020)	Laboratory	Colors	ABA	VR2/EXT, EXT/VR2, EXT/VR2	Y
88	Kimball et al. (2020)	Laboratory	Colors	ABA	VR2, EXT/EXT, EXT/EXT	Y
89	Kimball et al. (2020)	Laboratory	Colors	ABA	VR2, EXT/VR2, EXT/VR2	Y
90	Kimball et al. (2020)	Laboratory	Colors	ABA	VR2, EXT/VR2, EXT/VR2	N
91	Kimball et al. (2020)	Laboratory	Colors	ABA	VR2, EXT/EXT, EXT/EXT	Y
92	Kimball et al. (2020)	Laboratory	Colors	ABA	VR2, EXT/EXT, EXT/EXT	Y
93	Kimball et al. (2020)	Laboratory	Colors	ABA	VR2, EXT/VR2, EXT/VR2	Y

Note: Italics in Column 2 indicate the study used a design that combined renewal with another relapse phenomenon. Bolding in Column 7 indicates use of a mitigation technique. Design letters refer to contexts used during the baseline, treatment, and test phases (e.g., ABA = Context A during baseline, Context B during treatment, Context A during renewal test). VR = variable ratio. EXT = extinction. FR = fixed ratio. VI = variable interval. VT = variable time. Reinforcement schedules for an alternative response (e.g., compliance) follow backslashes. Reinforcement schedules with arrows indicate within-phase schedule thinning.

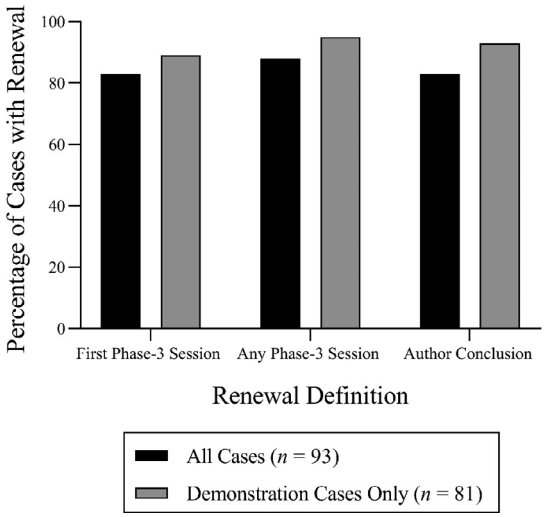

Fig. 1. Percentage of cases with renewal (including combined relapse) when defined as an increase in target behavior during the first session of Phase 3 relative to the last session of Phase 2 (first two bars), an increase in target behavior during any Phase-3 session relative to the last Phase-2 session (second two bars), or based upon the conclusions of the authors of each respective study (third two bars). Black bars include all 93 cases in which authors evaluated renewal or combined relapse whereas gray bars exclude cases from Kelley et al. (2018) and Kimball et al. (2020) aimed at reducing renewal (i.e., the remaining 81 cases were aimed at demonstrating, rather than mitigating, renewal).

Discussion

We reviewed the extant literature on human investigations of operant renewal to identify renewal demonstration and mitigation studies. We analyzed these studies to determine the breadth and scope of this literature base, determine what conclusions have been drawn from this literature, as well as identify barriers to studying the renewal effect unique to human participants. The operant renewal effect appears to be a robust phenomenon, supported by demonstrations in both clinical and human-laboratory studies, across a variety of variables, responses, contextual stimuli, schedules of reinforcement, and experimental preparations. This finding is generally consistent with nonhuman animal studies of operant renewal and provides further evidence of interspecies generality. However, there was only one study involving human participants that explicitly attempted to reduce or eliminate renewal of clinically meaningful behavior. Nonetheless, it appears that translational studies of operant renewal with humans comprise an emerging area of investigation.

Human-Experimental Research of Operant Renewal

Most of the studies identified in this review were laboratory investigations of renewal (i.e., human–operant preparations). These studies often relied on gross-motor response forms (e.g., mouse clicks, button-pressing), arbitrarily defined contexts (e.g., colors), and primary or generalized conditioned reinforcers (e.g., edibles, points). Translational investigations of renewal which are designed to bridge gaps between purely experimental and purely applied knowledge may be useful because studying renewal in clinical settings can be a fairly prohibitive endeavor (i.e., difficulty in studying socially meaningful behavior across environments, difficulty in obtaining caregiver buy-in, withdrawing interventions with the sole purpose of studying relapse). The value of this approach depends on the translation's ability to accurately replicate important variables relevant to applied situations (Mace & Critchfield, 2010).

Although laboratory studies involving humans appear to be an attractive method for studying factors affecting relapse, Wathen and Podlesnik (2018) suggested proceeding with caution in this approach, as they identified several challenges with conducting laboratory studies of renewal using humans. For instance, responding in these types of studies could be affected by the manner in which response materials are presented, fluctuation in motivation to contact reinforcement (e.g., the relative value of arbitrary reinforcers such as points on a computer), or complex verbal behavior and rule-following which may lead to persistent responding during the test for renewal. Results from these studies may inadvertently obscure the extent to which firm conclusions can be drawn about operant renewal with humans. Nonetheless, even under these arrangements and considering these limitations, operant renewal was observed in 60 of 71 human-laboratory cases (84.5%).

Clinical Research of Operant Renewal

A minority of cases attempted to study renewal using clinically relevant behavior. One

of the critical differences between experimental and clinical investigations of renewal with humans is the dynamic nature of changing context in real-world settings. Sullivan et al. (2018) noted that the difficulty in studying renewal with humans in clinical situations is that it is often impossible to expose individuals to isolated contexts in the traditional three-phase sequential manner (i.e., introducing each context sequentially), as is commonly done in experimental and translational research. Therefore, it is unclear to what extent the traditional model of operant renewal is reflective of treatment relapse due to contextual changes in typical settings. *Context* in the natural environment consists of individuals exposed to ever-changing environments and their associated contingencies wherein contextual variables can interact in novel ways. In addition to global settings such as home environments and clinic environments, there are additional stimulus conditions that could further define a context (e.g., Therapist A vs. Therapist B within a clinic setting). Sullivan et al. suggested that although the sequential three-phase design is useful for studying behavioral processes of relapse due to contextual change, this design needs to be refined to resemble what occurs in real-world situations and better mimic clinical intervention (i.e., context defined dynamically).

Given the dynamic nature of context in clinical situations, it is unclear which behavioral processes give rise to operant renewal under these circumstances. For example, Podlesnik and Miranda-Dukoski (2015) suggested that operant renewal observed in the target context may be a product of the degree to which stimulus features of that context are similar to the training or elimination contexts (i.e., Context A or B, respectively). However, static-stimulus conditions rarely exist in the natural environment and, under some circumstances, the target (generalization) context may resemble either the initial (training) context or the elimination (treatment) context. That is, it may be the case that, for a given individual, the generalization context sometimes shares features similar to the initial context and sometimes shares features of the elimination context (e.g., in a classroom setting the instructor could be either a teacher who represents one context or a teaching aide who represents a different context). Therefore, future research on the mechanisms of renewal as it relates to stimulus generalization gradients in applied situations is warranted.

It remains unclear to what extent relapse observed across settings can be attributed to contextual factors. For instance, along with introducing a behavioral treatment to a context associated with reinforcement for maladaptive behavior, is it not uncommon for newly taught appropriate behaviors to occasionally contact extinction (Fisher, Greer, Fuhrman, Saini, & Simmons, 2018), or for caregivers to make procedural-fidelity errors such as withholding reinforcers for appropriate behavior or delivering reinforcers following maladaptive behavior (Mitteer et al., 2018). In which case, it is likely that relapse that occurs with humans in clinical situations is a product of changing contexts (i.e., renewal), appropriate behavior going unreinforced (i.e., resurgence), and reinforcement of target responding (i.e., rapid reacquisition, Bouton, 2014; or response-dependent reinstatement, Podlesnik & Shahan, 2009). In natural settings, it is likely that all of these types of relapse combine in unique ways. Although isolating the impact of context on relapse is valuable, its significance should be considered in light of other relapse phenomena. It is possible that most relapse cases that occur with humans in clinical situations more closely resemble combined relapse wherein context and contingencies of DRA interact, increasing the overall magnitude of relapse (Podlesnik et al., 2019).

Differential Reinforcement and Operant Renewal

Most studies using nonhuman animals as subjects in renewal investigations arrange extinction when the response elimination phase is introduced (Podlesnik et al., 2017). However, outside of treatments for inappropriate mealtime behavior, extinction is rarely used alone. Clinical investigations most often combined extinction with differential reinforcement, as this practice has shown to lead to greater reductions in maladaptive behavior than extinction alone (Shukla & Albin, 1996).

Given that clinical investigations of renewal typically arrange DRA plus extinction instead of extinction alone during treatment, and that such treatment is often introduced in a context outside of the individual's usual environment, it is important to acknowledge potential

covariation between responses that are targeted for elimination and acquisition when the usual environment is reintroduced. For example, Saini et al. (2018) found that destructive behavior renewed during an ABA investigation of functional communication training, but also observed degradation of appropriate communicative behavior when the context associated with baseline contingencies was reintroduced. Similar results were obtained by Kelley et al. (2018) who observed reductions in compliance along with renewal of aggression during an ABA evaluation. These results suggest that reintroducing a context associated with a previously learned maladaptive behavior also affects rates of behavior acquired in an alternative DRA context, and reveals how context can impact treatment generality both in terms of appropriate and inappropriate behavior. This finding may be a product of response competition between recently acquired treatment-related contingencies for appropriate behavior and contextual control governing maladaptive behavior. Alternatively, it is possible that response-class hierarchies are influenced by the greater environmental context wherein the original context in which behavior was learned (maladaptive or appropriate) governs the order in which responses are expressed (Griffee & Dougher, 2002).

The use of DRA during the elimination phase relative to extinction alone may also influence the degree of renewal observed in humans. Using an ABA renewal design, Kimball et al. (2020) compared the effects of DRA plus extinction to extinction alone during the response elimination phase and found that extinction alone tended to produce greater levels of renewal compared to DRA plus extinction. This finding has particular relevance when studying relapse in humans and suggests that the degree of renewal observed in nonhuman animal studies that arrange extinction alone may not be reflective of the degree of renewal that might be observed in human studies that usually arrange DRA and extinction together.

Relatedly, Kimball et al. (2020) found that renewal was greater when engaging in the alternative response was made possible in the initial training context relative to when the alternative response was not made available. This is also relevant for applied studies of renewal given that treatments (and associated responses such as communication) are not typically introduced until after treatment is initiated in a new context such as in a clinic setting. This may explain why renewal was observed by Saini et al. (2018) during functional communication training given that those authors included communication materials in the original training context. However, it is unclear if introducing materials from a treatment context into the original training context that were not initially present significantly alter contextual control over maladaptive and appropriate behavior (resembling an ABC renewal paradigm as opposed to ABA). This might explain why Kimball et al. observed a smaller magnitude of renewal when they restricted response materials in the original training context, given that ABC renewal is a less robust phenomenon compared to ABA renewal (Liddon et al., 2018). Future researchers might consider resolving this issue given that almost all studies of behavioral intervention include some environmental manipulation of the original training context to establish new stimulus control in that environment (e.g., introducing alternative-response materials).

Mitigation of Renewed Maladaptive Behavior in Humans

Though researchers have suggested renewal mitigation strategies could be incorporated into behavioral interventions with clinical populations (Podlesnik et al., 2017), there is a paucity of research demonstrating renewal mitigation with humans. We identified only one study that attempted to mitigate renewal of a socially significant dependent variable. Kelley et al. (2018) used a context-fading procedure to successfully mitigate ABA renewal in three children diagnosed with autism spectrum disorder who engaged in maladaptive behavior (i.e., destructive behavior or inappropriate mealtime behavior). Their procedure consisted of incorporating generalization stimuli (e.g., pairing implementers, introducing the therapist into the test context) into the training context. They suggested that clinicians can modify contextual control by correlating intervention-specific stimuli with stimuli from a context associated with baseline contingencies.

The dearth of mitigation studies in the human literature relative to studies using nonhuman animals might reflect the difficulty in translating these strategies to applied situations (partly due to the nature of dynamic contexts described above). However, programming for generalization of treatments has been a longstanding goal of clinical behavior analysis and there is an abundance of literature demonstrating that treatments developed in one context can readily generalize to new contexts. Stokes and Baer (1977) described these strategies in a general sense and Podlesnik et al. (2017) detailed how these strategies could be used explicitly in conditions wherein renewal is likely to occur.

Many strategies for mitigating renewal described in nonhuman animal studies are consistent with generalization techniques used by clinical behavior analysts, such as: (a) systematically increasing the similarity between the context in which maladaptive behavior occurs and the context in which it is treated (e.g., having natural behavior-change agents implement treatments alongside therapists as a part of clinic-based intervention; Durand, 1999; Durand & Kishi, 1987; Moes & Frea, 2002; Wacker et al., 2005; referred to as "context fading" in the renewal literature and "incorporating common mediators" in the applied literature); (b) establishing discriminative control over appropriate behavior using treatment-correlated stimuli and introducing those stimuli to novel contexts (Fisher, Greer, Fuhrman, & Querim, 2015; Mace et al., 2010; referred to as "extinction cues" in the renewal literature and "programming common stimuli" in the applied literature); and (c) successively introducing the treatment to multiple contexts prior to the target context (Piazza, Hanley, & Fisher, 1996; referred to as "multiple-context training" in the renewal literature and "training sufficient exemplars" in the applied literature). Therefore, although only one study has demonstrated a renewal mitigation strategy with humans in an applied investigation, it is likely that clinical investigations of maladaptive behavior are circumventing the renewal effect by using generalization strategies described in the extant literature.

Indices of Renewal Effects in Humans

We evaluated the presence of renewal by comparing the relative increase in responding during the first session of the renewal test to the final session of the preceding treatment phase. However, some authors have used different criteria for determining if renewal occurred. For example, in Case 66 described by Ibañez et al. (2019), target responding increased during the fourth renewal-test session and the authors described this as renewal despite responding being low during the three preceding renewal sessions. Liddon et al. (2018) did not describe this as renewal for a similar delayed effect in Case 23. Although these cases were captured by our modified criteria which examined levels of target responding in *any* session of the renewal test phase, there is no agreed upon definition of how these delayed-renewal effects should be interpreted. Determining whether these cases are classified as renewal or not may be especially important when studying relapse in humans, given that similar effects have rarely been described in nonhuman animal research.

Kimball et al. (2020) deemed any session during the relapse test as renewal when responding increased above the last treatment session and above an 85% reduction criterion from baseline. For Cases 73, 78, and 89, this definition precluded Kimball et al. from describing the small increases in target responding as renewal. Similarly, Saini et al. (2018) did not describe Case 35 as renewal because the rate of the target response (i.e., self-injurious behavior) was considered too low, despite this case being identified as renewal when our objective criteria were applied. These discrepancies related to small-magnitude effects further highlight the need for researchers to use objective and measurable definitions of renewal.

One potential index of contextual control that has not been explored readily in renewal studies is the latency to target responding in addition to the rate of target responding. For example, two caregivers (Cases 28 and 31) in Mitteer et al. (2018) exhibited target responding (i.e., undesirable caregiver behavior) within 2 s of the relapse test. For Case 28, this was the only instance of target responding during the relapse test. This finding suggests the context change may have renewed target responding, but that responding decreased rapidly as it contacted extinction. For combined-relapse studies or DRA studies

using intermittent schedules of reinforcement (e.g., Kimball et al., 2020), reviewing within-session patterns to examine response latencies and the order in which responses occur may help to illuminate the processes responsible for relapse. For example, renewal may be more probable when target responding occurs shortly after the start of a session (i.e., upon reintroduction of the initial context or introduction of a novel context). This method may shed light on the delayed-renewal effect observed in various investigations involving human participants that is not commonly reported in nonhuman animal studies.

Limitations of Studying Renewal with Human Participants

One limitation of using humans as participants in renewal studies is that experimenters must better account for variables not often encountered with nonhuman animals, which can greatly affect interpretation of renewal data. One such threat is the influence of procedural fidelity on obtained results because experimenters or clinicians must respond to participant behavior according to a prescribed protocol. Although degradation in fidelity as a confound is a risk for any study that involves experimenters implementing the study's procedures, it is particularly relevant to clinical studies in which the session implementer is exposed to topographies of maladaptive behavior (e.g., aggression) that could likely challenge procedural fidelity. For example, it is difficult to implement attention extinction when aggression may produce some therapist reaction like response blocking or flinching (Hood, Rodriguez, Luczynski, & Fisher, 2019).

When examining the five studies (Ibañez et al., 2019; Kelley et al., 2018; Mitteer et al., 2018; Pritchard et al., 2016; Saini et al., 2018) that evaluated renewal of clinically meaningful behavior, three reported fidelity results. Of those three studies (Ibañez et al., 2019; Mitteer et al., 2018; Saini et al., 2018), only Saini et al. (2018) described fidelity during the renewal test specifically. That is, Ibañez et al. (2019) and Mitteer et al. (2018) described fidelity only collapsed across experimental phases and did not describe the form of errors when fidelity was imperfect (e.g., reinforcer omission vs. delivery; phase in which error occurred). Future studies should aim to report fidelity across all phases, especially during the renewal test if other variables besides the context change might be responsible for relapse.

Another difference between renewal studies using humans compared to nonhuman animals is that experiments are often conducted across calendar days wherein participants are exposed to different contexts and contingencies between and within experimental phases. Ibañez et al. (2019) indicated that their investigation of ABA renewal of inappropriate mealtime behavior took between 5 to 10 business days to complete and in their results indicated when a new day began. For the majority of participants, increases in inappropriate mealtime behavior were observed on the first session of a new day, both in the elimination phase (i.e., therapists implementing extinction) and in the reintroduction of the original context in the final phase (i.e., caregivers implementing extinction). Given that this increase in responding was observed in both contexts, it is unclear if relapse during the reintroduction of the original context was due to renewal (or delayed renewal) or simply spontaneous recovery of inappropriate mealtime behavior on each new day. That is, the absence of experimental sessions for an extended duration following extinction of a previously reinforced response (i.e., inappropriate mealtime behavior) could have led to the reemergence of the response (Wathen & Podlesnik, 2018). Although it is likely that the majority of renewal investigations using humans with clinically meaningful behavior will occur across days, the role of contextual change versus spontaneous recovery on relapse could be studied empirically by comparing responding across days in which extinction was in effect and the context was not changed, to responding across days in which extinction was in effect and the context was changed on a given day. Differences in responding under these circumstances should highlight the role of context change alone.

Implications for Quantitative and Qualitative Theories of Renewal

Results from studies involving human participants may have significance for theoretical accounts of operant renewal, given that renewal and resurgence appear to be related and entangled phenomena in humans (e.g.,

Podlesnik et al., 2019). Although standalone accounts of renewal have received attention in the extant literature (Todd, Vurbic, & Bouton, 2014b), a more useful account based on the available data on renewal with humans may be one in which renewal and resurgence are regarded similarly or are the product of the same underlying process (e.g., Bouton et al., 2012). As demonstrated in studies of combined relapse in humans (e.g., Mitteer et al., 2018), it may be erroneous to artificially separate renewal effects from resurgence, as the variables that give rise to relapse are likely to interact under naturalistic conditions.

Bouton et al. (2012) have suggested that reinforcement and extinction contingencies form different stimulus contexts that contribute to the resurgence of a previously reinforced behavior (i.e., differences in response-contingency relations represent contextual differences, and as a result relapse due to resurgence could be attributed to contextual variables; Bouton et al., 2012; Winterbauer & Bouton, 2010). However, this account has been criticized for being unfalsifiable and it is therefore unknown if this represents a meaningful advancement of theories of relapse (Shahan & Craig, 2017).

Most studies of renewal based on general quantitative theories of relapse (e.g., behavioral momentum theory) have focused on examining how differences in response acquisition and contextual variables influence the degree of renewal observed (e.g., Berry et al., 2014; Podlesnik & Shahan, 2009). However, stimulus control appears to be the central principle governing relapse due to contextual changes, and no general quantitative theory of stimulus control as it relates to relapse exists. Podlesnik and Kelley (2014) also suggested that competition between contingencies of reinforcement and stimulus control as observed in studies of combined relapse have failed to be accounted for by existing theories of relapse such as behavioral momentum theory (see also Nevin et al., 2017).

Resurgence as Choice (Shahan & Craig, 2017), as a general quantitative model of recurrent behavior, may have implications for relapse in clinical situations or under naturalistic settings (Greer & Shahan, 2019). However, the current model has not yet been extended to account for the role of contextual variables that may give rise to renewal. Given that resurgence and renewal are often intertwined, a reasonable extension of this theory would be one that incorporates context change as an important variable in relapse.

There are clear differences between nonhuman animal and human studies of renewal that should be incorporated into a quantitative and testable theory of relapse. Theories of relapse that fail to account for variables that exist outside of the experimental laboratory could facilitate clinical research that lacks social significance (e.g., using schedules of reinforcement common in purely experimental work, but uncommon in applied settings; Fisher et al., 2019). Studying basic processes of relapse using nonhuman animals is the first course of action to develop quantifiable and testable theoretical accounts of contextual influences on behavior. However, it is equally important that accounts of renewal that are designed to represent human behavior incorporate variables from real-world settings. This approach would likely lead to meaningful translational and clinical research, ultimately culminating in techniques useful for applied practice. Ignoring variables unique to applied settings and how these variables interact in the natural environment may lead to (a) theories that lack concurrent validity with the phenomenon they are designed to represent and (b) potentially misinform applied research based on those theories.

The results of renewal investigations with humans have provided a number of consistent findings that may be important to incorporate into a theoretical account of relapse. First, a theory of relapse should incorporate dynamic changes in context, as it appears that the traditional three-phase procedure lacks construct validity with how rapidly contexts change under natural conditions. Second, a quantifiable theory based on differential reinforcement may be more valuable than one based on extinction alone, although an initial quantitative account will likely need to begin with studies of extinction alone. Third, it is not unusual for renewal to be delayed with human participants, and considering variables that account for delayed renewal may be valuable.

Conclusion

Our review suggests that a number of studies have demonstrated the renewal effect with human participants across different design

types (e.g., ABA, ABC, and AAB). However, in some situations, the observed relapse effects could be due to context in combination with other factors (e.g., resurgence, procedural-fidelity errors, spontaneous recovery). Therefore, quantitative theories of relapse designed to account for renewal effects might benefit by examining the role of context change in combination with variables known to produce other types of relapse (e.g., resurgence). Future researchers should continue to refine methods to isolate the effects of context on relapse, to the extent possible given the aforementioned challenges. Doing so may bring to light how context functions to produce undesirable behavior in general theories of relapse.

We recommend future research focus on consolidating the literature on renewal mitigation strategies with techniques designed to promote generalization of treatment effects (i.e., those described by Stokes & Baer, 1977). Doing so may produce a more robust technology for sustaining treatment effects in real-world settings. We suggest that this research begin by assessing the pragmatic value of laboratory approaches to mitigating renewal prior to conducting clinical investigations. It is clear that investigations of operant renewal in humans are an emerging area of interest and studies examining the role of contextual variables on instrumental learning will likely continue to grow in the future. There is a bright future for translational research in this area given the prevalence of treatment relapse when treating behavior disorders across socially meaningful contexts.

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