A Comprehensive Systematic Review of Procedures and Analyses Used in Studies of Resurgence, 1970-2020

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Abstract

Resurgence is the return of a previously reinforced response as conditions worsen for an alternative response, such as the introduction of extinction, reductions in reinforcement, or punishment. As a procedure, resurgence has been used to model behavioral treatments and understand behavioral processes contributing both to relapse of problem behavior and flexibility during problem-solving. Despite the study of resurgence for over half a century, there have been no systematic reviews of the basic/preclinical research on resurgence. To characterize the procedural and analytic methods used in this area of research, we performed a systematic review of the basic/preclinical research on resurgence consistent with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. We identified 120 articles consisting of 200 experiments that presented novel empirical research, examined operant behavior, and included standard elements of a resurgence procedure. We reported prevalence and trends in over 60 categories, including participant characteristics (e.g., species, sample size, disability), designs (e.g., single subject, group), procedural characteristics (e.g., responses, reinforcer types, control conditions), criteria defining resurgence (e.g., single test, multiple tests, relative to control), and analytic strategies (e.g., inferential statistics, quantitative analysis, visual inspection). We discuss the relevance of existing procedural and analytic methods for future laboratory research and development of translational and clinical research on resurgence of problem behavior.

Keywords: Resurgence; relapse; basic research; data analysis; systematic review

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Introduction

Resurgence is the return of a previously reinforced operant behavior with the *worsening* of more recently available alternative reinforcement and associated response conditions (see Lattal et al., 2017; Shahan & Craig, 2017). Most commonly, the worsening of alternative conditions has been demonstrated when a previously reinforced and extinguished target response increases as an alternative response encounters reduced reinforcer availability through extinction or decreases in alternative-reinforcer rate or magnitude (e.g., Craig et al., 2017a; Winterbauer & Bouton, 2012). Furthermore, resurgence can also result from introducing punishment contingencies (Fontes et al., 2018) or greater response effort (Wilson et al., 2016) for engaging in the alternative response. Because operant responding returns after elimination with extinction, resurgence indicates that extinction does not erase or destroy original learning. Instead, the elimination of responding during extinction reflects a change in performance that reflects new learning. As a result, the worsening of alternative conditions producing resurgence is related to a class of other extinction phenomena, including changes to contextual stimuli producing renewal, re-presenting reinforcing events or related stimuli producing reinstatement, and time away from experimental conditions producing spontaneous recovery (see Bouton et al., 2021, for a review). Identifying variables contributing to resurgence is scientifically important not only because of its relevance to understanding fundamental behavioral processes contributing to choices in changing environments but also to understanding factors contributing to relapse of clinically relevant behavior (see Wathen & Podlesnik, 2018).

The phenomenon of resurgence is clinically relevant because behavioral interventions designed to eliminate problem behavior typically arrange reinforcement for more appropriate behavior (e.g., Higgins et al., 2013; Tiger et al., 2008). During treatments of challenging problem behavior for individuals diagnosed with intellectual and developmental disabilities (e.g., autism spectrum disorder, ASD), differential reinforcement of alternative behavior (DRA) procedures provide reinforcement for appropriate behavior (e.g., polite requests, card exchange) while typically also arranging extinction of problem behavior (e.g., tantrums, self-injury). Resurgence of the target problem behavior can occur when alternative-reinforcement conditions worsen (1) by programming reinforcement thinning to make DRA treatments more manageable or (2) inadvertently from treatment-integrity errors resulting in the omission of alternative-reinforcer presentations following appropriate behavior (see Briggs et al., 2018; Muething et al., 2020; Volkert et al., 2009). Similarly, any reductions in delivery of alternative reinforcement during behavioral interventions for substance abuse disorders, such as phasing out contingency management (e.g., Silverman et al., 1999), would result in reduced incentives for appropriate behavior and increased likelihood of resurgence. Identifying variables contributing to resurgence can lead to the development of approaches to enhance the long-term effectiveness of behavioral interventions arranging alternative reinforcers.

Basic and preclinical research can serve to identify variables influencing resurgence that are of foundational and clinical interest. Some of this research arranged preclinical models to develop and assess procedures designed to produce more durable behavioral interventions by mitigating relapse (e.g., Shvarts et al., 2020; Trask, 2019) and other research has evaluated conceptual and quantitative frameworks from which to assess theories and fundamental behavioral processes potentially underlying resurgence (e.g., Bai et al., 2017; Bouton, 2019; Nevin et al., 2017; Podlesnik et al., 2022; Shahan & Craig, 2017). The first apparent laboratory report of the resurgence of operant behavior was presented by Carey (1951) but the procedures arranged in Carey's report are somewhat atypical (cf. Reed & Morgan, 2007). Carey arranged reinforcement across the first two phases and extinction in the third phase for two groups of rats responding on the same bar in all phases. The rats were required to make a single response per reinforcer or two temporally spaced responses per reinforcer, with these response requirements counterbalanced between the first two phases across groups. During extinction testing, Carey reported a decrease in the response pattern from the more recent phase and, importantly, a return in the originally reinforced response pattern – the effect now termed resurgence.

As in Carey (1951), modern laboratory models of resurgence similarly take the form of three phases (e.g., Epstein, 1983; Leitenberg et al., 1970; Winterbauer & Bouton, 2010). Figure 1 shows a basic and typical set of procedures arranged to examine resurgence, along with hypothetical data. During Phase 1, Training typically includes a baseline in which a target response is acquired as a result of contingent reinforcer deliveries. In laboratory models assessing relapse, Training models the baseline levels of problem behavior established under natural conditions. During Phase 2, Elimination typically includes extinction of the target response and initiating reinforcement of an alternative response. Elimination simulates a behavioral treatment, such as DRA, often resulting in the decrease or elimination of target responding and acquisition of alternative responding. Finally, Testing in Phase 3 models the worsening environmental conditions that challenge the long-term maintenance of behavioral treatments (Nevin & Wacker, 2013). As shown in the figure, the most basic form of Testing for resurgence involves worsening alternative conditions by arranging extinction of an alternative response. There is typically a transient increase in target responding, the resurgence effect, with both responses progressively decreasing with additional exposure to Testing across time/sessions (see Podlesnik & Kelley, 2014, 2015, for a discussion of other response patterns during Testing).

Since Carey's (1951) initial report, there have been hundreds of experimental studies demonstrating the generality of conditions in which resurgence occurs (see Kestner et al., 2018a; Shahan & Craig, 2017; Wathen & Podlesnik, 2018, for reviews). Participants include multiple species of nonhumans and different populations of humans with and without clinical diagnoses. Designs have included a variety of between- and within-subjects comparisons using a range of control conditions. The influence of a wide variety of conditions on the size, pattern, and reliability of resurgence effects have been examined, including differences in learning history, reinforcer types, response types, contingencies for delivering alternative reinforcers, and methods for worsening alternative-reinforcement conditions. Finally, there have been numerous approaches to analyzing resurgence data, both to define resurgence and evaluate whether a resurgence effect occurred relative to control conditions, groups, and responses. Existing reviews conducted on basic research in the resurgence literature convey the generality of resurgence. However, these reviews have been narrative and either conceptual (e.g., Kestner & Peterson, 2017; Lattal et al., 2017; Pritchard et al., 2014) or theoretical (e.g., Shahan & Craig, 2017; Shahan & Sweeney, 2011). As a result, these reviews have not (1) attempted to characterize comprehensively the procedural and analytic methods used in the basic experimental literature on resurgence or (2) taken steps to counter potential biases (e.g., selection biases) and threats to generality (e.g., inability to replicate findings revealed in the review). Systematic review, in contrast, features exhaustive search procedures (e.g., ancestral, individual hand searches) and communicates all of the procedures necessary to replicate the findings of the search at a later date (e.g., specific search criteria, Boolean operators). This approach provides the opportunity to exhaustively review the range of procedural and analytic methods used in the resurgence literature in a transparent, standardized, and replicable manner (e.g., Gilroy et al., 2017, 2018; Perrin et al., 2021).

Research Questions

The purpose of the current review was to comprehensively and systematically report the procedural and analytic methods used to study resurgence in basic/preclinical laboratory research. We characterized participants, designs, procedures, and analyses used in basic experimental research on resurgence. Based on the findings from this review, we characterize patterns and trends in procedural and analytic methods used in the extant literature and discuss areas for further research. Therefore, we address the following research questions in this review:

RQ1) What species and populations have been examined in studies of resurgence?

RQ2) What experimental designs have been used to examine resurgence?

RQ3) What procedural manipulations have been arranged when examining resurgence?

RQ4) How has resurgence been defined empirically during data analysis?

RQ5) What approaches have been used to analyze resurgence data?

Methods

Literature Search Methods

We conducted a systematic search of the available literature to evaluate research examining resurgence phenomena, as shown in Figure 2. The search methods used in this study were consistent with the guidelines presented in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) approach. The databases included in the original search consisted of Education Resources Information Center (ERIC), PSYCInfo, Medline, and ScienceDirect. The specific keywords and Boolean operators provided to each of the databases consisted of the following: resurgence AND relapse OR operant OR extinction OR reinforcement. Following the identification of suitable articles, ancestral searches were performed to examine references for other potentially-relevant works. Upon the completion of ancestral searches, hand searches for all journals that featured resurgence-related content were manually searched to identify whether relevant works were published but not yet indexed in databases.

Study Selection

Keyword searches for all databases were performed independently by two of the study authors. This initial phase of the search consisted of screening titles and abstracts to determine whether they were potentially eligible for inclusion in the study. For potential studies which had full-text resources available, two authors independently reviewed the methods and results to confirm that the work was suitable for inclusion in the review. Across each phase of the review, disagreements between raters were resolved via discussion until a consensus was reached. The initial searches of the ERIC, PSYCInfo, Medline, and ScienceDirect databases between April of 2021 and May of 2021 resulted in 27, 343, 150, and 3060 articles, respectively.

Criteria for Study Inclusion

Studies eligible for inclusion in the review met several criteria. Specifically, eligible articles presented novel empirical research, examined operant behavior, were available electronically in full text, written in English, were peer-reviewed, did not examine clinically relevant problem behavior, and included all elements of a resurgence procedure. To include all elements of a resurgence procedure, at least one assessment (e.g., group, condition) within the experiment must include all of the following elements:

1. During Training, a target behavior was reinforced.

2. During Elimination, contingencies were designed to decrease target behavior by removing the reinforcer maintaining target behavior and arranging alternative reinforcer deliveries differently from Training.
3. During Testing, the contingency governing alternative reinforcer deliveries changed from Elimination in a way designed to assess potential increases in target responding.

Given that published review articles did not constitute empirical research, these were not featured as elements summarized in the final results (e.g., Lattal et al., 2017; Shahan & Craig, 2017). However, the reference lists of these works were reviewed to determine whether supporting works were eligible for inclusion in the study. Other examples of articles that did not meet our inclusion criteria included those that did not reinforce an explicit target response during Training (Cançado et al., 2017), did not remove the reinforcer maintaining target responding during Elimination (Bouton et al., 2017; Houmanfar et al., 2005; Nall et al., 2019; Nall & Shahan, 2020), or only arranged Training followed by Testing with extinction, thereby omitting Elimination (Herrick, 1965; Mechner et al., 1997; Mechner & Jones, 2011).

Coding Strategy

All studies deemed eligible for inclusion in the research synthesis were coded along several dimensions to address the research questions, as described in the sections below.

Participant Characterization

We identified the population of participants within each experiment. We recorded different species and different populations of participants within species in terms of age/development (e.g., children vs. adults) and source of recruitment (e.g., university vs. crowdsourcing). We also coded humans based on whether or not a specific diagnosis was included when describing the participants in the articles.

Experimental Methodologies

Fixed-procedural characteristics referred to aspects of methods that were not manipulated during experiments – they were not independent variables. These characteristics included the number of experiments, groups, and group sizes. We determined the number of experiments per article based on how the data were analyzed. In some cases, experiments were designated as "sub-experiments" (e.g., 1a, 1b) and considered separate experiments because the data from the experiments were primarily analyzed separately (e.g., Nighbor et al., 2018; Trask, 2019). In other cases, sub-experiments were considered a single experiment because data from those experiments were analyzed together (e.g., da Silva et al., 2008). Also, if experiments from one article (Podlesnik & Shahan, 2010) were included from an earlier article (i.e., Podlesnik & Shahan, 2009), we only included those experiments when coding the earlier article. When experiments included different numbers of participants across groups, we recorded the highest and lowest sample sizes. Other characteristics included method of arranging experimental sessions across time (e.g., single session, multiple sessions) and number of testing data points when determining resurgence (single or multiple); method of changing phases (fixed or performance-based; and types of experimental designs used to examine independent variables, including specific within-subject manipulations and whether two or more phases were replicated directly within subjects.

Procedural Manipulations

Procedural manipulations included the greatest number of dimensions to code, including antecedent-stimulus manipulations, approaches to mitigate resurgence, control conditions or groups, and aspects of responses and consequences (e.g., reinforcement, punishment). We primarily included variables that were manipulated in at least a subset of experiments. For example, most experiments including an inactive control response did not manipulate the number of control responses available but a subset of experiments did (e.g., Cox et al., 2019; Diaz-Salvat et al., 2020). However, for simplicity of organization, we also coded for characteristics of reinforcement schedules and reinforcer types in this section, which included variables that were not manipulated but relevant to those dimensions. When coding for characteristics of reinforcement schedules, we coded whether reinforcers were delivered via free-operant behavior or within discrete trials, the presence of a changeover requirement, and the use of response sequences. Similarly, the presence or absence of using backup reinforcers for points or tokens (e.g., money, course credit) was not manipulated within experiments but was relevant to characterizing the types of reinforcers arranged across resurgence experiments.

Definitions of Resurgence

All experiments included at least one criterion to define whether resurgence occurred. Examples include comparisons of target responding between Elimination and Testing, with control groups or assessments, relative to control responses, unspecified increases in target responding, and others. Articles typically identified relevant criteria when presenting results (e.g., Hernandez et al., 2020) but some articles identified the criteria defining resurgence as part of the analytic strategy before presenting results (e.g., Kuroda et al., 2020).

Analyses of Resurgence

All experiments analyzed data by examining response patterns from individual participants and/or employed some kind of statistical analysis. These analyses were conducted on one or more direct measures (e.g., response rate) or derived measures (e.g., proportions, differences), which we also coded. Finally, we reported whether theoretical frameworks were used to simulate effects or were fit to data, including behavioral momentum theory (Nevin et al., 2017), resurgence as choice (Shahan & Craig, 2017), and generalization theory (Bai et al., 2017).

Inter-Rater Reliability

All prospective studies were independently screened, inspected, and scored by the first and second authors. Studies screened, inspected, and confirmed to be eligible for inclusion were scored based on the coding strategy listed in the previous section. The data extraction procedures were performed with the aid of a specialized spreadsheet instrument. This tool supported raters in examining the relevant features of included works as well as in assessing agreements and disagreements. After each rater independently scored respective works, the spreadsheet detected disagreements, and these disagreements were resolved via discussion until consensus was reached and 100% agreement was demonstrated across raters.

Results

As shown in Figure 2, an initial search of the included databases returned a total of 3,580 results. Results of initial reviews revealed that 809 (22.6%) articles were relevant to the research questions. From this quantity, 608 of the search results were found to be duplicated entries (75.15%; n=808-608=201 unique entries). Full-text resources were then inspected and 131 articles (65.17%) were found to be relevant to the research questions. Ancestral searches were performed for each of these studies and yielded a total of 26 additional articles. Hand searches for all relevant venues yielded an additional 16 articles. Among the total 173 works determined relevant to resurgence, 120 were empirical studies and 53 were review articles.

Overview

The 120 empirical articles included in this review represent 200 distinct experiments across 20 different journals spanning the years 1970 to 2020. As a result of so many experiments meeting our inclusion criteria, this review primarily presents the prevalence of the different participants, methods, and analyses used in these experiments.[1]

The outcomes of the review can be examined in several ways. First, tables present counts, percentages out of the 200 experiments, and representative example experiment(s) of the categories described in the text. Second, the online interactive table can be used to organize and identify all experiments meeting user-specified criteria from the categories examined in this review (https://miyamot0.github.io/Table.html). Finally, the Supplemental Materials present figures with the same counts and percentages as in the tables but, when relevant, provides a more detailed narrative with additional published examples of experiments meeting the different criteria. The Supplemental Materials also include definitions of the variations of criteria included within the different sections of this review.

Figure 3 shows cumulative articles across years and the number of articles per year. The rate of publication remained steady and relatively infrequent with at most 1-2 articles published per year for the first 35 years. Over three-fourths (76.7%) of all articles on resurgence were published in the last 10 years, from 2011 to 2020. Figure 4 shows the journals publishing articles on resurgence, with the *Journal of the Experimental Analysis of Behavior* leading the count with 39 articles.

RQ1: Participant Characterization

Table 1 shows that 13 different nonhuman and human populations comprise participants in resurgence experiments. Therefore, resurgence as a behavioral phenomenon is general across species and populations, but rats, pigeons, and university students together make up the vast majority (88.5%) of participants out of the 200 experiments included in this review. Overall, 149

[1] This is in contrast to most systematic reviews that describe, for example, specific variations of procedures for all experiments included in the review (e.g., Gilroy et al., 2017, 2018; Perrin et al., 2021).

experiments (74.5%) included nonhumans as participants. Of the 51 experiments (25.5%) including human participants, ten experiments (5.0%) included individuals diagnosed with a developmental disability, with two of those experiments (1.0%) employing a combination of children with and without diagnoses – the remaining 41 experiments (20.5%) employed typically developing adult humans (e.g., university students).

Commentary

Resurgence has been examined across a wide range of species and therefore appears to be a general phenomenon. It is important to note that, by excluding clinical research in the context of behavioral interventions such as DRA (e.g., Kestner & Peterson, 2017; Perrin et al., 2021; Radhakrishnan et al., 2020, for reviews), the present review under-represents the generality of resurgence, particularly with individuals diagnosed with developmental disabilities. However, nearly 9 out of 10 experiments have been conducted with the same three populations (i.e., rats, pigeons, and university students). There have been no examinations of resurgence, for example, in species of invertebrates, amphibians, or reptiles. Thus, further research is needed to examine the generality of resurgence across the animal kingdom.

RQ2: Experimental Methodologies

We report the experimental research designs and other fixed procedural features arranged within experiments when examining resurgence. In other words, we examined the prevalence of fixed design and procedural features that were not arranged as independent variables manipulated across evaluations of resurgence (e.g., groups, replications). Table 2 shows experiments organized based on design type and whether participants were humans or nonhumans.

Fixed Procedural Characteristics

Experiments Per Article. Table 3 shows that most articles presented only a single experiment. As can be observed in the table, the counts of experiments generally decreased with increases in experiments per article.

Groups Per Experiment. Table 4 shows that most experiments arranged only a single group per experiment. These counts generally decreased with increases in groups per experiment.

Session Arrangement. Table 5 shows that experimental sessions were arranged either within or between days. Including one or more sessions per day across multiple days was by far the most common approach, followed by the entire experiment arranged during a single visit, and then multiple individual sessions within a single day.

Testing Arrangement. Single data points during Testing allow for the comparison of initial differences in resurgence effects while multiple data points offer the evaluation of response patterns over time. Table 6 shows that multiple data points were more commonly arranged during Testing than single data points.

Phase Changes. Rules for transitioning from Training to Elimination, Elimination to Testing, and to end Testing were based either on performance factors (e.g., stability criteria) or were fixed, independent of performance, and based on the amount of time, number of sessions, number of trials, or number of reinforcers earned. Table 7 shows that (1) more experiments arranged fixed criteria than performance-based criteria across conditions and (2) the prevalence of using fixed criteria increased across conditions and use of performance-based criteria decreased across conditions. Two additional experiments (1.0%) not included in Table 7 were categorized as “other” for Training because they arranged both performance-based and fixed criteria across multiple successive assessments of Training, Elimination, and Testing.

In addition, 14 experiments (7.0%) also not presented in Table 7 included an additional phase during Elimination that arranged extinction of target responding before introducing and reinforcing an alternative response (e.g., Winterbauer & Bouton, 2011, Expt 1-3). This manipulation has been used to examine processes involved in resurgence (see Shahan & Sweeney, 2011, for a review).

Experimental Designs

Table 8 shows the types of experimental designs used to examine resurgence. Within-subjects designs were most common. Less prevalent were between-subjects (group) designs, combinations of within- and between-subjects designs, and an inductive design.

Within-Subjects Manipulations. Within-subjects designs were defined as experiments examining both individual-subject data (e.g., single-subject designs) and data from multiple participants summarized as a single group with no other comparison groups. Thus, other than Multiple Approaches, the present section identifies within-subject manipulations arranged in isolation within an experiment in the absence of other within- or between-subject manipulations. Table 8 shows, in part, the types and prevalence of within-subjects manipulations arranged across all 200 experiments.

None. These experiments did not include any within-subject manipulations when assessing resurgence other than arranging the relevant within-subject contingency changes across Training, Elimination, and Testing to assess resurgence. Some of these experiments provided *demonstrations* of resurgence with novel variables (e.g., participant population, procedural feature) or systematically replicated a previously published report. The remainder of experiments identified in Table 8 arranged either at least one within-subject manipulation of an independent variable, as described next, or employed between-subjects or inductive designs.

Multiple Assessments. These experiments arranged multiple assessments, either by directly replicating two or more phases (see below) or by arranging different conditions within one or more phases across successive assessments. To elaborate upon the latter, these included Training, Elimination, and/or Testing with variables changed (1) across successive exposures to one or more of those phases or (2) across time within a phase.

Phase Replications. Direct replications are a specific form of Multiple Assessent repeating any two or more phases of Training, Elimination, and/or Testing across successive presentations of phases. Table 9 shows the prevalence of experiments arranging phase replications. Note that some experiments including phase replications also were categorized as Multiple Approaches because they included other within-subjects manipulations (see below).

Multiple Schedule. In the experiments arranging multiple schedules, they presented within-session alternations of two or more discriminative stimuli. Multiple schedules facilitated the examination of the influence of separate contingencies or other events presented within the component stimuli.

Multiple Responses. These experiments arranged the successive differential reinforcement of more than one response or response sequence within or between phases. These manipulations facilitated the examination of primacy and recency effects in the resurgence of operant behavior.

Concurrent Schedule. These experiments arranged for two target responses to be available simultaneously throughout Training, Elimination, and Testing. Concurrent schedules facilitated the examination of the influence of separate contingencies or other events simultaneously across phases.

Multiple Approaches. Finally, these experiments examined the effects of more than one independent variable on resurgence using combinations of two or more of the within-subjects designs described above.

Between-Subjects Designs. Between-subjects designs arrange for different groups of participants to receive different manipulations or levels of an independent variable within one or more of the Training, Elimination, and Testing phases.

Combinations of Designs. These designs examined manipulations of one or more independent variables between subjects while also manipulating one or more other independent variables using one of the within-subjects designs described above.

Inductive Design. We described an "inductive" design as experiments using the prevalence of resurgence effects for a group exposed to one set of conditions to determine changes to the independent variables of interest arranged for a subsequent group. This process can be repeated until a certain predetermined prevalence of resurgence is met within a given group or the experiment is terminated without meeting the prevalence criterion.

Commentary

The breadth of within- and between-subject experimental designs used to examine a multitude of variables suggests that researchers have a powerful set of methods to understand variables and processes involved in resurgence. We identified that a majority of experiments employed within-subjects designs, which generally are effective and efficient for examining functional relations between independent and dependent variables because each participant serves as one's own control (see Iversen, 2013; Sidman, 1960). Within-subject designs can eliminate the variability in data that comes with assessing the effects of variables between groups of participants. There are some limitations, however, to using within-subjects designs when attempting to examine multiple variables contributing to resurgence. Repeated exposure to stimuli and/or contingencies comprising these procedures can confound resurgence findings and, as a result, make interpreting effects difficult. Specifically, repeated presentation of one or more of the phases comprising resurgence procedures can decrease (e.g., Kestner et al., 2018a; Podlesnik et al., 2020) or less commonly increase (e.g., Cleland et al., 2000; Redner et al., 2022) resurgence across subsequent tests. Therefore, the benefits of within-subjects designs must be weighed against the cost that learning acquired during any of the Training, Elimination, and Testing phases could affect resurgence during subsequent exposures to those phases.

In particular, examining the effects of novel procedures hypothesized to reduce resurgence (see mitigation strategies below) relative to a standard set of resurgence phases could produce different outcomes depending on whether the novel procedure was arranged first or second. Arranging a mitigation strategy during a first assessment would expose participants to the mitigation strategy, which could generalize and mitigate responding during the second assessment. In contrast, exposure to a mitigation strategy during the second assessment confounds the potential mitigation of resurgence with the effects of repeatedly assessing resurgence. If researchers have access to enough participants to meet statistical power, between-subjects assessments might be more appropriate. However, nearly half of the studies in the present review included six or fewer participants, potentially indicating limited access to large samples of participants. Some within-subject designs provide appropriate alternatives to between-subject assessments for small-*n* studies. For example, researchers could arrange a single exposure to Training and Elimination followed by relatively rapid alternation between Testing conditions (e.g., Kimball et al., 2018; Shvarts et al., 2020, Expt 1-2), or that each component of a multiple schedule could present different variables during relevant phases (e.g., Houchins et al., 2022; Lambert et al., 2015). In summary, the most appropriate design to examine resurgence likely will differ depending on sample size and the specific variables being examined.

We also identified that most experiments examining resurgence in nonhumans arranged consecutive phases and sessions across days (e.g., Shahan et al., 2020a). In contrast, most experiments examining resurgence in humans arrange much briefer exposure to procedures, oftentimes entirely within a single visit. These relatively brief procedures are practical for use with humans and have effectively demonstrated resurgence effects using both within- (e.g., Houchins et al., 2022) and between-subjects designs (e.g., Bolívar & Dallery, 2020). However, there have been no comparable studies of resurgence effects in which nonhumans have been exposed to such brief conditions. We identified only one example of relatively extended exposure to contingencies with humans (Kuroda et al., 2016). The different durations of exposure to experimental conditions could underlie differences observed between humans and nonhumans in levels of responding on unreinforced control responses (e.g., Sweeney & Shahan, 2016; Nighbor et al., 2020), used as a measure of control by the Training reinforcement contingency over resurgence versus induced variability (see Lattal & Oliver, 2020, for a critical review). Research comparing extended versus brief exposure to Training, Elimination, and Testing contingencies with human and nonhuman populations would contribute to identifying the influence of reinforcement contingencies versus induced variability in examinations of resurgence.

RQ3: Procedural Manipulations

Experiments evaluating resurgence have examined a wide range of stimulus-, response-, and reinforcer-based independent variables across Training, Elimination, and Testing. This section characterizes these variations across resurgence experiments.

Antecedent-Stimulus Conditions

The influence of some form of antecedent-stimulus change was assessed in 24 experiments (12.0%; e.g., Podlesnik et al., 2019, Expt 1-3). These experiments arranged at least one within- or between-subject change in the contextual or discriminative stimuli across one or more phases of Training, Elimination, and Testing.

Resurgence Testing

Table 10 shows the prevalence of experiments examining conditions influencing resurgence, including extinction in isolation, within- or between-subject comparisons of different conditions, and demonstrations of non-extinction conditions. Most experiments assessed resurgence exclusively by arranging alternative reinforcement during Elimination and then completely removing alternative reinforcement during Testing. Some experiments examined other conditions and have broadened or refined the range of variables influencing resurgence. Of these, most arranged within- or between-subject comparisons to compare different reinforcement or stimulus conditions that might contribute to resurgence. Other experiments examined only a single Testing condition other than simply eliminating alternative-reinforcer deliveries but nevertheless this line of research demonstrated resurgence occurs under non-extinction conditions. The Supplemental Materials provide detailed descriptions and examples of approaches used to examine resurgence other than with extinction in isolation, both through the worsening of alternative conditions and through changes to the alternative conditions.

Mitigation Techniques

Preclinical-research models can be used to evaluate approaches to mitigate the resurgence of problem behavior but under well-controlled conditions compared with clinical settings (see

Wathen & Podlesnik, 2018). Table 11 shows the prevalence and examples of procedures that could be considered approaches designed to mitigate resurgence.

Thinning/Decreased Reinforcement. These experiments examined the effects of gradual reductions in the rate, magnitude, or immediacy of alternative reinforcement on the resurgence of target responding, in contrast to abruptly eliminating alternative reinforcement with extinction.

Context/Stimulus Changes as Treatment Cues. These experiments arranged antecedent or consequence stimuli during Elimination and examined whether also presenting those stimuli during Testing influenced resurgence.

Response-Independent Reinforcer Deliveries. These experiments examined whether the reinforcer delivered during Elimination would decrease resurgence if presented response independently during Testing.

Punishment. These experiments examined whether punishment contingencies arranged during Elimination relative to no punishment contingency influenced resurgence, including the use of shock with nonhumans and point loss or timeout presentations with humans.

Extended Elimination. These experiments modeled different differential-reinforcement treatment durations to examine whether longer durations of Elimination could mitigate resurgence relative to shorter durations.

Multiple Alternatives. These experiments examined whether reinforcing multiple alternative responses during Elimination could mitigate resurgence relative to the more typical approach of arranging only a single alternative response.

Drug Effects. These experiments, exclusively with rats, examined whether pre-session injections of drugs could decrease resurgence of target responses either to test potential pharmacotherapies in a resurgence model of relapse of drug use or to examine the neuropharmacology contributing to resurgence and relapse more generally.

On/Off Contingencies. These experiments arranged repeated alternations between reinforcement and extinction of alternative responding during Elimination and examined resurgence during extinction during Testing.

Abstinence Contingency. These experiments arranged, during Elimination, a contingency in which engaging in the target response delayed the availability of response-contingent alternative reinforcers. These methods were designed to model interventions for drug abuse based on contingency management-based interventions (e.g., Higgins et al., 2013).

Multiple Approaches. These experiments examined more than one of the resurgence-mitigation strategies described above, specifically the presence versus absence of on/off contingencies and different durations of Elimination, or extended elimination.

Control Conditions

A critical component for evaluating whether and/or the extent to which particular experimental manipulations contribute to resurgence effects are the inclusion of appropriate control conditions. Table 12 shows the prevalence of five different manipulations observed in this literature that provide control conditions during resurgence procedures.

Inactive Control Responses. One procedural control arranges opportunities to engage in the one or more inactive response(s) throughout Training, Elimination, and Testing but no reinforcement is available for responding. Any increases in control responses during Testing typically have been interpreted as induced variability, rather than a resurgence effect (see Lattal & Oliver, 2020, for a critical review). As shown in Table 12, the number and form of control responses varied across experiments.

Typical Resurgence Procedure. Some experiments examined a "typical" resurgence effect to compare with the effects of novel manipulations of independent variables on resurgence. These controls included conditions or groups omitting any additional experimental manipulations other than target reinforcement during Training, a consistent source of alternative reinforcement and removal of the reinforcer maintaining target responding during Elimination, and Testing with an extinction contingency.

No Alternative Reinforcement During Elimination. These experiments arranged a simple extinction contingency for target responding without alternative reinforcement during Elimination. This control can identify (1) how effectively an alternative source of reinforcement contributes to decreasing target responding during Elimination and (2) the smallest degree of change in target responding that could accompany the transitioning from Elimination to Testing.

Omission of Training. These experiments omit Training and present only Elimination and Testing. Omission of Training identifies whether a history of reinforcement for target responding versus other processes influences increases in target responding during Testing. If target responding increases with the omission of training, then increases in target responding with the inclusion of Training might only reflect induced variability or other processes (see Lattal & Oliver, 2020).

Presenting Alternative Reinforcement During Testing. Finally, presenting alternative reinforcement throughout Testing identifies the smallest degree of increase in target responding during the transition from Elimination to Testing.

Response Characteristics

We characterized the type of target, alternative, and inactive control responses arranged in resurgence experiments across a number of dimensions. This section first focuses on the topography of responses and then reports whether experiments included an alternative response during Training.

Target- and Alternative-Response Topographies. Table 13 shows that experiments typically arranged the same target- and alternative-response topography but others arranged different topographies or compared different types of alternative responses. Table 14 shows that most experiments arranged one alternative response but others arranged no alternative response, such as in conjunction with response-independent or DRO contingencies. Some experiments arranged multiple alternative responses and others compared different numbers of alternative responses. Finally, Table 15 shows the different response topographies arranged for target and alternative responses. Examples can be identified in the online interactive table and Supplemental Materials.

Control-Response Topography. Table 15 also shows the different control-response topographies, with examples available from the online interactive table and Supplemental Materials. Most experiments did not arrange any kind of inactive control response. The most common control responses involved manipulanda, followed by responses on a computer screen, a computer keyboard, an activity, and breaking a photosensor. Finally, experiments with children examined control-response topographies in participants' repertoires that were never reinforced during experimental sessions, including emotional or other responses likely functionally equivalent to target responding.

Presence or Absence of Alternative Response During Training. Table 16 shows that under half of the resurgence experiments included an alternative response during Training. Therefore, most experiments did not include an alternative response during Training. Typically, no rationale is provided for including or excluding the alternative response during Training but some experiments have compared the effects of the presence versus absence of the alternative response during Training. In the miscellaneous cases that did not fit with the above categories, the alternative responses included skills that might or might not have been in participants' repertoires and a comparison between different Elimination procedures (e.g., math).

Reinforcement Schedules

Table 17 shows whether the reinforcement schedules arranged between Training and Elimination were identical, different, or arranged a comparison. Most experiments arranged a different reinforcement schedule between Training and Elimination and others arranged the same schedule. The remaining experiments arranged a comparison of reinforcement schedules between Training and Elimination, with Training and Elimination schedules being the same in at least one assessment and different in at least one assessment.

Target and Alternative Reinforcement Schedules. Table 18 shows the reinforcement schedules arranged during Training and Elimination. Most experiments arranged some kind of partial-reinforcement schedule, a comparison of different reinforcement schedules, or continuous reinforcement within the Training and Elimination phases. Other experiments arranged during Training and Elimination for reinforcers to be presented contingent upon combinations of contingencies, duration of responses, and the relative frequency of a response. The experiment labeled "Other" arranged reinforcement across participants according to a range of continuous- and partial-reinforcement schedules during Training and Elimination but the schedules were not examined as an independent variable. Progressive ratios and response-dependent plus response-independent reinforcer deliveries were unique to Training. In contrast, omission schedules, response-independent schedules, lag schedules, and engaging in an activity were unique to Elimination.

Other Reinforcement-Schedule Characteristics. Table 19 shows procedural features related to the relations between responding and reinforcer deliveries that were not formally a component of the reinforcement schedules. These included the use of free-operant versus discrete-trial procedures, the use of changeover requirements between responses, and requiring response sequences to obtain reinforcement.

Deceleration Procedures during Elimination

Table 20 presents the type of procedure arranged to decrease target responding during Elimination. Most experiments arranged extinction of target responding while reinforcing an alternative response (DRA), while others arranged a comparison of different procedures. Other experiments exclusively arranged omission (DRO) contingencies, reinforced a different response sequence during Elimination than during Training, presented alternative reinforcers response independently (i.e., noncontingent reinforcement, NCR), or arranged extinction of target responding in isolation before reinforcing an alternative response in isolation. Less commonly, experiments reinforced target responding in one component of a multiple schedule and an alternative response in another component during Training or reinforced different response durations within chain schedules.

Reinforcer Types

Table 21 displays the prevalence of experiments arranging identical, different, or a comparison of reinforcer types between Training and Elimination, with most experiments arranged using the same type of target and alternative reinforcers. Another experiment arranged combinations of reinforcers during Training but only edible reinforcers during Elimination.

Target- vs. Alternative-Reinforcer Type. Table 22 presents the prevalence of target and alternative reinforcer types – see Supplementary Material or the interactive online table for specific examples of experiments arranging the different reinforcer types. Edible/food reinforcers were considerably more common than other reinforcer types, with point deliveries with human participants being the next most prevalent. The prevalence of edible reinforcers increased from Training to Elimination, largely driven by experiments with nonhumans arranging drug self-administration during Training and nondrug food reinforcers during Elimination. The other reinforcer types are described in greater detail with examples in Supplementary Material.

Backup Reinforcers. Most experiments did not arrange backup reinforcers during Training (179 experiments, 89.5%) and Elimination (181 experiments, 90.5%) but arranged positive or negative reinforcers previously demonstrating effectiveness as a consequence of operant behavior (see above). In contrast, 40 experiments (20.0%) with human participants arranged within-session earnings of points or stimulus presentations on a computer screen with no demonstrated functional relevance. Therefore, some of these experiments arranged backup reinforcers delivered sometime following sessions or participation with the purpose of enhancing control by within-session events (see Hackenberg, 2009, 2018). Table 23 shows the prevalence of arranging backup reinforcers contingent upon within-session performance through providing post-session access to money, edibles, the opportunity to earn a gift card or money through lotteries, or access to unspecified but empirically demonstrated preferred items. Of the experiments with humans arranging in-session earnings of points or stimulus presentations, 19 experiments (9.5%) during Training and 21 experiments (10.5%) during Elimination arranged no backup reinforcers (see online interactive table).

Of the 38 experiments (19.0%) employing university students as participants, 26 experiments (13.0%) provided course credit for participating in research. Table 24 shows that most of the experiments providing course credit arranged delivery of credit contingent on the duration of participation with no other performance-contingent backup reinforcers. In contrast, a subset of the experiments arranging course credit also arranged backup reinforcers contingent upon in-session performance.

Punishment Types

Table 25 shows experiments examining the effects of punishment on resurgence, including shock presentations with nonhumans and, with humans, the effects of response cost, negative performance feedback, and timeout.

Commentary

A wealth of research suggests that resurgence of target responding fundamentally is a result of worsening of alternative conditions, as demonstrated by decreases in alternative-reinforcer rate/magnitude and increased delays (see Lattal et al., 2017, for a review). An important contribution to the line of research supporting this conclusion is the worsening of alternative conditions by arranging punishment of alternative responses during Testing (Fontes et al., 2018; see also Wilson & Hayes, 1996). However, Fontes et al. found modest decreases in reinforcer rate accompanied shock deliveries contingent upon alternative lever pressing in rats. Because changes in variables other than decreasing reinforcement rate can enhance resurgence effects (e.g., Kincaid et al., 2015), the punishment contingency might have served both to decrease reinforcer rates by decreasing alternative response rates and further contribute to the resurgence effect in addition to the influence of decreases in reinforcement rate. Therefore, eliminating decreases in alternative-reinforcement rates during punisher deliveries (e.g., response-independent reinforcer deliveries) and arranging equivalent decreases in reinforcement rates in the absence of punisher deliveries would be important control tests to strengthen these conclusions.

Control conditions isolate the degree to which the worsening of alternative conditions influences resurgence. As described previously, the use of inactive responses controls for the worsening of alternative conditions producing a selective increase in target responding resulting from the history of reinforcement during Training (i.e., resurgence), rather than inducing general increases in behavioral variability. In research with nonhumans, resurgence effects generally have been unambiguous because changes in levels of inactive responding from Elimination to Testing tended to be minimal relative to increases in target responding (e.g., Kuroda et al., 2017a, 2017b). In the subset of experiments with adult-human participants that have arranged button presses and included inactive response options, in contrast, worsening alternative reinforcement conditions frequently resulted in increases in both target and inactive responses during Testing (e.g., Cox et al., 2019; cf. Thrailkill et al., 2019). One conclusion is that it is unclear is whether the same behavioral processes underlying resurgence in nonhumans underlies resurgence in humans, at least under these types of laboratory conditions.

Lattal and Oliver (2020) suggested there could be multiple reasons for nonhumans typically engaging in few inactive responses during Testing, in addition to the selective effects of reinforcement history on the resurgence of target responding. For instance, inactive responses might not be sufficiently salient to be discriminated as an available option – if so, the inactive responses might as well not be present. Nevertheless, most experiments with nonhumans record some low but non-zero level of inactive responding (e.g., Craig et al., 2020, Expt 1-2; Kuroda et al., 2017a; Shvarts et al., 2020, Expt 1), suggesting discrimination of the presence of inactive options. Moreover, identifying those variables in research that influence the likelihood of humans engaging in inactive controls, of which there are many (e.g., response effort, motivation for reinforcers), is likely important for several reasons. First, identifying functional relations between variables that minimize or induce inactive responding in both humans and nonhumans would be useful for identifying the conditions and behavioral processes involved in resurgence and related phenomena. Second, consistency between laboratory models employing humans and nonhumans would offer the opportunity to develop and assess preclinical models across species and be more confident we are examining similar phenomena – important for translational research. Finally, identifying variables influencing inactive responding with humans could help identify the influence of higher-order behavior on resurgence (e.g., counting, self-rules).

An interesting and potentially relevant case is Thrailkill et al. (2019, Expt 1-2), who reported minimal levels of inactive responding during Testing with humans pressing keys on a computer keyboard for target, alternative, and four inactive options. They provided an instruction specifying that participants could access the reinforcer by pressing the "yellow buttons" which were the target and alternatives, while the inactive buttons were colored over with black marker. Furthermore, they specified that, *"...you will know which is the right button because it will make something happen…"*. Although there were other features to Thrailkill et al. that were unique among experiments with humans (e.g., participant-exclusion rates, reinforcer types), the low levels of inactive responding likely could have been maintained by instructional control. If so, these findings suggest an influence of higher-order processes in resurgence, and that developing procedures to examine common behavioral processes in resurgence between humans and nonhumans will require creative approaches, including potentially requiring human participants to engage in other distracting activities (e.g., counting backward by 7s; see Barnes & Keenan, 1993; Reed, 2020). Finally, the use of specific keys on a keyboard could differ from using other types of buttons, as humans might engage with computer keyboards differently from other types of buttons.

A major difference in research employing adult humans versus research with children and with nonhumans is the reinforcers typically are evolutionarily relevant with children and nonhumans (e.g., food) but are not with adult humans (e.g., points). Most resurgence research with humans employed university students who participate for course credit (e.g., Galizio et al., 2020; Houchins et al., 2022). Although such incentives motivate students to participate in research generally, it is unclear how or whether course credit motivates students' performance during these tasks. Consequences purportedly serving as reinforcers (e.g., points) with students generally have not been assessed and demonstrated to serve as effective reinforcers other than through instructional control, in contrast with research employing children (e.g., Shvarts et al., 2020, Expt 2) and nonhumans (e.g., Craig et al., 2020, Expt 1-2). Some experiments with adult students arranged for participants to earn, in addition to course credit, within-session backup reinforcers dependent on performance (e.g., money, gift cards). However, it also is unclear whether such incentives effectively served as reinforcers under these conditions (e.g., Podlesnik et al., 2020; Williams & St. Peter, 2020, Expt 1-2). It is unknown whether the arrangement of such backup reinforcers enhances control by within-session events, but research on the effectiveness of token delivery within token systems indicates effective backup reinforcers are necessary (see Hackenberg, 2009, 2018). Therefore, further research exploring methods for identifying effective reinforcers with adult humans could generally enhance engagement with the tasks. Such research could increase the comparability of research with different populations and species, including the involvement of fundamental behavioral processes we described above with regard to engaging in inactive response options.

Finally, this section demonstrated there is a wealth of research examining qualitative and quantitative antecedent-, behavior-, and consequence-based variables influencing resurgence.

Although numerous variables have yet to be examined systematically (e.g., response effort, interactions between different target and alternative reinforcer types), an important area for further research is in understanding neurobiological processes in resurgence. Studies examining the neurobiological underpinnings of relapse are common in research on other relapse-like phenomena, including reinstatement (e.g., Werner et al., 2021) and renewal (e.g., Bouton et al., 2021). However, only three experiments have examined pharmacological effects in the context of resurgence (e.g., Cook et al., 2020, Expt 2; Quick et al., 2011; Pyszczynski & Shahan, 2014), and only the latter two experiments attempted to examine whether pretreatments of selective receptor agonists and antagonists influenced resurgence generally (rather than as a potential strategy to mitigate drug self-administration). Therefore, research examining the neurobiological processes underlying resurgence effects is needed.

RQ4: Definitions of Resurgence

Conclusions about whether resurgence occurred can depend on how researchers define a resurgence effect. In fact, 60 experiments (30.0%) used more than one approach to defining resurgence. We reported twelve different approaches used to define whether resurgence occurred during Testing, as shown in Table 26.

The most common approach referred only to unspecified increases in target responding with no reference to, for example, target responding in other phases or relevant control responses Other approaches defined resurgence as increases in target responding during the first assessment during Testing (e.g., session, time period) relative to the last assessment during Elimination, target responding being greater than levels of inactive-control responding during Testing, greater levels of target responding across multiple assessments during Testing relative to the last assessment during Elimination, greater levels of target responding across multiple assessments during Testing relative to levels of target responding across multiple assessments during Elimination, and greater levels of target responding relative to target response rates occurring in a control group or control assessment. Less common approaches to defining resurgence included target responding being greater than alternative responding during Testing, greater levels of responding during an isolated Testing session relative to levels of responding during an isolated Elimination session, target responding being statistically greater than chance levels, target responding occurring at least one time during Testing, or the highest rate of target responding during any session of Testing exceeding the rate of target responding during the last session of Elimination.

Commentary

The different approaches to defining resurgence described above exist primarily to account for the variety of procedural details across experiments. Of the twelve different approaches we identified to define resurgence, all but one made reference to one or more specific criteria. The exception was the most prevalent approach that did not specify a resurgence effect beyond referring to increases in target responding. There are some instances of target-response increases large enough to result in little question about whether resurgence occurred relative to appropriate comparisons. Nevertheless, defining clear and specific criteria used to determine the presence of a resurgence effect is useful to other researchers, especially if there is considerable variability in the data during Elimination or Testing.

A common approach to defining resurgence was to assess whether target responding increased during Testing to levels greater than one or more data points during Elimination. There were 117 experiments (58.5%) with 128 instances overall using this approach. There are some important implications for conclusions about resurgence effects worth considering among the specific approaches employing this general strategy.

First, comparing target responding during Testing with either a single data point versus multiple data points during Elimination could have different implications for defining resurgence. For example, taking into account multiple data points over time during Elimination is more stringent, as it accounts for levels of variability demonstrated during Elimination. If there was variability in target responding across, for example, the last five data points during Elimination, it could indicate that any increase during Testing might not be due to the worsening of conditions (i.e., resurgence) but instead to a continuation of the levels of variability observed during Elimination (see Pigeon 449, Jarmolowicz & Lattal, 2014). Using the same criterion when target responding during Elimination was on a consistent downward trend would potentially rule out a resurgence effect (i.e., Type II error). Only implementing phase changes from Elimination to Testing when target responding reaches a sufficient level of stability resolves this issue. Extending Elimination until stability is reached, however, might not always be practical or desirable. For example, fitting quantitative models to all participants from between-subjects data requires all participants experience the same number of sessions or some data must be omitted. If participants receive different durations of exposure, one option employed has been to use the number of sessions arranged for the majority of participants (e.g., Podlesnik & Shahan, 2010). An alternative is to remove some portion of data from Elimination (e.g., beginning of Elimination) to equate the duration of exposure across all participants. Therefore, criteria for defining resurgence can have broad impacts on the general analytic strategy.

A final point to consider with this general approach of comparing Elimination and Testing is whether multiple data points are assessed during Testing. Multiple data points during

Testing allow for the assessment of resurgence patterns. For example, different Testing conditions can produce inverted U-shaped patterns of target responding while others a monotonic decrease in responding (e.g., Podlesnik & Kelley, 2014) that has informed the development of quantitative analyses (see Shahan & Craig, 2017). Thus, multiple data points during Testing offer the opportunity to fit quantitative theoretical models to the pattern of resurgence. The quality of fits to patterns of resurgence can be useful for identifying relevant behavioral processes (e.g., Bai et al., 2017; Shahan et al., 2020a, 2020b).

RQ5: Analyses of Resurgence

An additional important component to defining what patterns of data constitute resurgence are the analyses used to verify those effects. Analyses were comprised of those that are statistical or used visual inspection, direct recording of events or those calculated or normalized in relation to other anchoring data, and the use of quantitative theoretical frameworks to simulate or analyze model fits.

General Analytic Strategy

Researchers have used different approaches to analyzing within- and/or between-subject data to determine whether independent variables investigated in this research contributed to the occurrence, reliability, and size of resurgence effects. Table 27 shows the different general analytic approaches used across experiments. Most experiments either analyzed data using visual inspection to examine data from individual subjects within an experiment or a traditional frequentist approach to inferential statistics that test null and alternative hypotheses. Other experiments used both visual inspection of individual-subject data and a frequentist approach to statistical inference. Finally, one experiment used mixed-effects modeling.

Specific Measures of Resurgence

As was the case with different definitions of resurgence, different measures can provide insight into different aspects of resurgence data. As such, Cançado et al. (2016) provided an in-depth description of uses for different types of measures of resurgence. Direct measures present resurgence data as direct reporting of behavioral events, in contrast to derived measures that report resurgence data through comparison with other events.

Direct Measures. Table 28 presents the prevalence of the use of direct measures. A vast majority of experiments reported one or more direct measures, with 53 experiments (26.5%) using multiple direct measures to analyze resurgence data. Most experiments reported response rate or count followed by responses emitted across time with cumulative records. Relatively infrequently used direct measures were comprised of intervals including a target or other response during Testing, latency to engage in a target response during Testing, the number of changeovers between response options, response duration, and the prevalence in counts of participants engaging in particular response patterns across Training, Elimination, and Testing.

Derived Measures. Table 29 shows measures that present resurgence data derived through comparison with other events, typically responding under different contingencies. Sixty-five experiments (32.5%) reported one or more derived measures of resurgence. The most common derived measure presented target responding during Testing as a proportion/percentage of target responding during Training. The next most common approaches were to examine target responding (1) by subtracting responding during Elimination from responding during Testing, (2) as a proportion/percentage of all other response options during Testing, (3) during Testing as a proportion/percentage of responding during Elimination, and (4) as a function of the range of response rates arranged across assessments.

The remaining derived measures were used relatively infrequently, including examining the difference in target responding between two multiple-schedule components during Testing as a proportion/percentage of target responding during Training. Another calculated the correlation between target responding during Testing and other measures. Other experiments reported levels of variability in target responding during Testing using a U-value statistic, the number of instances in which target responding occurred during Testing as a proportion of total opportunities to engage in target responding during Testing, response force during Training, Elimination, and Testing as a percentage of each participant's maximum force recorded during a pretraining assessment, and the proportion of response sequences meeting the lag contingencies arranged to obtain reinforcer deliveries.

Quantitative Analyses

Use of theoretical models is standard across sciences. Theories allow researchers to precisely quantify and directly compare the effects of variables on underlying behavioral processes (Mazur, 2006; Nevin, 1984; Shull, 1991). They also allow researchers to summarize existing findings and make predictions about how and why variables should affect measures based on model assumptions. Models used in research on resurgence include behavioral momentum theory (see Nevin et al., 2017), a stimulus-control model of temporal-discrimination performance (see Bai et al., 2017), and resurgence as choice (RaC; Shahan & Craig, 2017).[2] A detailed evaluation of the models used in research on resurgence is beyond the scope of this review and these details have been presented in the citations above and elsewhere. It is also worth noting that a conceptual model based on contextual changes and the renewal effect also

[2] The experiments reported in Figure 16 include the original and a modified version of RaC, known as Resurgence as Choice in Context (RaC^2). RaC^2 improved fits over RaC by incorporating parameters to account for biases toward the alternative-response option or away from both target- and alternative-response options, depending on alternative-reinforcer conditions during Elimination (see Shahan et al., 2020a, 2020b).

underlies research on resurgence (see Podlesnik & Kelley, 2015; Shahan & Craig, 2017; Trask et al., 2015, for reviews). This contextual model is not incorporated into this systematic review because no formal quantitative analyses specifically identify its use.

Table 30 shows the prevalence of using three different models. These models were used to make predictions about resurgence based on model simulations and/or to identify the influence of specific behavioral processes on resurgence through fits to data. Behavioral momentum theory was used most frequently in simulations and model fits.

Commentary

Directly recording aspects of behavior suffices under relatively simple conditions, such as when common Training and Elimination phases precede different Testing conditions or response rates between groups or conditions are equivalent during Training and Elimination. In contrast, derived measures that examine relations between dependent measures can be used to control for different and more complex patterns of responding across Training, Elimination, and Testing. However, assessing resurgence under multiple conditions, such as across groups, components of a multiple schedule, or concurrently available responses, can yield different frequencies of target responding during Training or Elimination. For example, higher rates of target responding in Training tend to correlate with greater levels of resurgence (e.g., da Silva et al., 2008; Sweeney & Shahan, 2013a; Winterbauer et al., 2013). Similarly, there are cases in which target responses that are more persistent during Elimination influence the degree of change in responding during Testing (see Nevin & Wacker, 2013; Podlesnik & DeLeon, 2015, for discussions; cf. Craig & Shahan, 2016). In such cases, when Training or Elimination responding differ across comparisons, examining response measures during Testing relative to the measures during

Training (e.g., Podlesnik & Shahan, 2009, Expt 1) or Elimination (e.g., Fontes et al., 2018) can control for those prior differences in response levels.

Relatedly and also important to selecting approaches to define resurgence in RQ4, researchers should also take into account the fact that different measures sometimes can result in different conclusions (see Cançado et al., 2016). For example, response rates during Testing sometimes are equal across groups or conditions (e.g., Craig & Shahan, 2016). No difference in resurgence would be concluded if examining only target response rates during Testing. In contrast, different conclusions about a resurgence effect would result if examined relative to response rates during either Training or Elimination. Moreover, response rates compared with Training versus Elimination would result in different conclusions if response rates differed in opposite directions between Training and Elimination. Therefore, measures might need to be compared and contrasted to provide the most appropriate account of resurgence effects.

While most experiments (>60%) used visual inspection to analyze data, over half incorporated statistical tests such as *t*-tests and ANOVAs. These types of statistical tests aggregate variability in responding within groups or across time periods; as a result, data of interest to behavior analysts is lost (e.g., individual-subject variability). Furthermore, these tests assume that data points are independent (i.e., behavior at one observation in time does not affect behavior in the next observation) and this is a continued challenge to the use of traditional statistics in single-subject designs. However, more advanced statistical methods relax these assumptions, and as such, are better suited to these arrangements of data. For example, multilevel (i., mixed-effects) modeling is an approach that accounts for individual-level variability within population-level estimates and this preserves individual-subject variability for later inspection and analysis (see DeHart & Kaplan, 2019; Kaplan et al., 2021). Similarly, these benefits are also possible using a Bayesian framework (see Young, 2019). Nevertheless, multilevel modeling was used only in a single experiment in the present review (Frye et al., 2018) but has been used in more recent experiments (e.g., Ritchey et al., 2021, 2022). Therefore, we recommend that, wherever appropriate, researchers take steps to integrate more robust modeling approaches into both within- and between-subject assessments of resurgence.

The empirical research described above has identified a range of variables functionally related to resurgence effects (see also Lattal et al., 2017, for a review). Quantitative theoretical models of resurgence go a step further by providing potential explanations – they assume specific roles for behavioral processes potentially underlying variables influencing resurgence (e.g., Bai et al., 2017; Nevin et al., 2017; Shahan & Craig, 2017). In particular, these models propose specific processes by which a reinforcement history for target responding persists through extinction and alternative-reinforcement conditions during Elimination, and that reinforcement history is expressed as resurgence upon worsening the alternative conditions, typically through extinction. Despite initiating the quantitative theoretical analysis of resurgence (Podlesnik & Shahan, 2009, 2010; Shahan & Sweeney, 2011), behavioral momentum was shown to be an inadequate account of the patterns of responding during Elimination (e.g., Craig & Shahan, 2016) and during Testing (Podlesnik & Kelley, 2014).

Thus far, research evaluating the other models of resurgence has been limited. In the case of the stimulus-control model introduced by Bai et al. (2017), it has only been applied to data collected from a free-operant psychophysical procedure so its generality remains to be examined. With regard to RaC, this model has been evaluated somewhat more extensively. In its first evaluation of its fits to resurgence data, it was modified from its initial form by Shahan et al. (2020a) to account for sustained biasing effects of reinforcement. When compared with behavioral momentum theory, this modified version (i.e., RaC^2) provided superior fits to parametric manipulations of different Elimination durations and an on/off alternative-reinforcement contingency. Subsequently, Shahan et al. (2020b) found that RaC^2 accounted well for resurgence effects when parametrically manipulating different levels of reduction in alternative reinforcer rate. The most recent research using RaC^2 was outside the time range of this review but has evaluated its fits with human participants via crowdsourcing; specifically, these studies examined changes in alternative reinforcer rates and magnitudes during Elimination (Podlesnik et al., 2022, Expt 1-4) and different durations of Training and Elimination (Smith & Greer, 2022). Although Smith and Greer found good fits of RaC^2 to their data, Podlesnik et al. required an additional free parameter to RaC^2 to provide an adequate fit for their data. This *misallocation* parameter assumed imperfect control by reinforcer distributions across response options (see Davison & Nevin, 1999; Cowie et al., 2021).[3] Nevertheless, the application of quantitative theoretical analyses to resurgence likely cannot yet be considered a mature area of research. As such, we recommend additional experiments evaluating these models' ability to account for parametric manipulations of the variables described above in this review. One variable not yet evaluated is a parametric manipulation of response effort, which could be examined across target, alternative, and/or control responses (cf. Wilson et al., 2016). Such research will facilitate our understanding of variables contributing to resurgence by examining whether these models account for the effects of variables related to antecedents, behavior, and consequences and whether additional assumptions or frameworks are needed.

[3] The fits of Smith and Greer (2022) were improved by allowing a free parameter in the RaC2 model (i.e., d_m) to be unconstrained and estimates fell below 1.0. In contrast, Podlesnik et al. (2022) constrained this parameter to be greater than 1.0 because they determined that constraining the model would be more consistent with assumptions of the model. This parameter being greater than one suggests target extinction and alternative reinforcement should only increase bias toward alternative responding, not away as assumed by estimates below 1.0.

Finally, Context Theory is a conceptual theory that accounts for resurgence effects as an instance of a more general phenomenon known as *renewal* (see Trask et al., 2015). Specifically, the contingency changes arranged across Training, Elimination, and Testing serve as different stimulus contexts – consequences produce resurgence through antecedent control. With regard to the target response, reinforcement results in excitatory conditioning during Training (Context A) and extinction plus an alternative reinforcer during Elimination results in inhibitory control (Context B). The worsening of alternative conditions during Testing changes the context yet again, comprising a novel Context C. According to this framework, resurgence is the return of extinguished operant responding during Testing in the presence of novel contextual stimuli because excitatory conditioning from Training generalizes across conditions more than the inhibitory conditioning subsequently established during Elimination.

A good deal of careful experimental research has provided support specifically for a context-response mechanism underlying relapse-like phenomena, including resurgence (see Bouton et al., 2021, for a review). Nevertheless, this theory has been criticized for a lack of predictive precision (see Shahan & Craig, 2017). There are findings in which manipulations logically would be predicted to make a context more salient (e.g., longer Elimination, greater alternative reinforcer rates) but have nevertheless failed to consistently produce different levels of resurgence (Winterbauer & Bouton, 2010, Expt 1-2; Trask et al., 2018, Expt 1). This predictive ambiguity that comes with Context Theory accompanying such quantitative manipulations (e.g., alternative reinforcer rate) could be less problematic under other experimental manipulations.

After Training with one reinforcer/outcome type (O1), Trask et al. (2018, Expt 2) arranged two novel reinforcer types contingent upon an alternative response across alternating sessions during Elimination. One reinforcer type (O2) was present during extinction of alternative responding but the other reinforcer type (O3) was presented in the absence of extinction of target responding. When presenting both novel reinforcer types in successive sessions during Testing, resurgence of target responding was lower when presenting O2 than O3. Trask et al. attributed the lower resurgence to O2 acquiring inhibitory control during Elimination because it accompanied extinction of target responding, while O3 did not. These findings provide support for conceptualizing consequences as comprising the contextual features that contribute to resurgence. Furthermore, despite the concerns about the precision of predictions relative to quantitative theoretical frameworks (see Shahan & Craig, 2017; Podlesnik & Kelley, 2015), the idea that reinforcers serve a discriminative role has received ample empirical support across a range of research domains (e.g., Cowie et al., 2021; Davison & Nevin, 1999; Franks & Lattal, 1976). For these reasons, the discriminative role of reinforcers resulting in contextual control over resurgence has been incorporated into quantitative models of resurgence (see Bai et al., 2017; Shahan et al., 2020a, 2020b). Additional experimental research and theoretical development are needed to determine whether quantitative theoretical analyses could provide adequate accounts of resurgence data under conditions thus far only examined during tests of a contextual account of resurgence (e.g., Bouton & Trask, 2016, Expt 1-3; Trask et al., 2018, Expt 2).

Discussion

We conducted the first systematic review of the basic/preclinical laboratory resurgence literature from 1970 to 2020. From the 200 experiments spanning 120 empirical articles, we reported the participants, research-design elements, procedural manipulations, definitions of resurgence, and the types of analyses used to characterize resurgence. This area of research is growing, with rates of publication generally increasing across years, particularly since approximately the year 2010. This literature demonstrated broad generality of resurgence across populations and experimental designs, which underlies our understanding of factors likely influencing aspects of dynamic behavior outside the laboratory, both in clinically relevant populations (e.g., Briggs et al., 2018; Muething et al., 2020) and in situations requiring problem-solving (Shahan & Chase, 2002; Williams & St. Peter, 2020). The present review can serve as a starting point in organizing this literature across a wide range of categories and, therefore, offer a guide for researchers conducting further research within these categories that could include empirical research, more focused and detailed reviews and meta-analyses, and quantitative analyses. In addition, this review might serve as a template for systematic reviews of other literature examining relapse phenomena, including studies of renewal, reinstatement, and others.

Preclinical research provides a platform from which researchers can identify methods for improving the durability of clinical interventions (see Wathen & Podlesnik, 2018). Purpose-driven translational research that integrates research from basic and clinical investigations is common in biomedical research (e.g., Edgeworth et al., 2020). The study of resurgence similarly has reflected the convergence of basic and clinical investigation, with initial clinical research demonstrating the generality of resurgence with clinically relevant behavior during DRA interventions (e.g., Lieving et al., 2004; Volkert et al., 2009). Design of clinical interventions for problem behavior likely will benefit from purpose-driven translational research designed to identify methods to increase the long-term effectiveness of reinforcement-based treatments.

We suggest some promising avenues for purpose-driven translational research. First, the validity of preclinical models could be assessed and developed to better simulate both problem behavior and common clinical interventions (e.g., DRA). Treatment for severe-problem behavior often involves reinforcing an alternative that is topographically different from the target behavior, such as a functional communication response. In contrast, most studies in the present review (>65%) arranged the same response topography between target and alternative responses. Second, research that has identified potential strategies to mitigate resurgence through antecedent-based (e.g., Shvarts et al., 2020) and consequence-based (e.g., Fisher et al., 2018) interventions could be explored further to identify combinations that are more effective than any in isolation. Several mitigation strategies attempt to offset decreases in alternative reinforcement by increasing generalization between Elimination and Testing (see Bouton, 2019; Podlesnik et al., 2017, for reviews). Finally, relatively recent research has shown some success in using quantitative models of resurgence (BMT, RaC) to predict resurgence of clinically relevant behavior and suggests potential approaches to optimize target- and alternative-reinforcement conditions (e.g., Fisher et al., 2018). Identifying, refining, and developing quantitative theoretical models that can effectively prescribe approaches to mitigating resurgence of problem behavior is a challenging but important direction for translational researchers.

Finally, the present review shows the number of studies examining resurgence and our understanding of the conditions in which resurgence occurs has expanded greatly, especially in the last 10-15 years. Examining relapse of any form of problematic behavior through the perspective of resurgence follows a tradition consistent with behavior analysis and learning theory with the goal of identifying relatively discrete events and experiences contributing to instances of relapse. The present review attempted to define these events within the basic/pre-clinical literature in a comprehensive way. In contrast, relapse can also be characterized by more extended environmental and biological risk factors, such as psychiatric comorbidities (e.g., Sliedrecht et al., 2019) or discounting of reinforcers (e.g., Yeh et al., 2020). Research examining how such extended risk factors and local events interact (e.g., Reed, 2019) can begin to provide a more comprehensive picture of the events contributing to relapse. Systematic review provides an important step in organizing basic/preclinical research for advancing our understanding relapse in the context of clinical intervention.

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Tables

Table 1. Populations of Participants, Counts, Percentages, and Examples

Participant Population	Count	Percentage	Examples
Rats	80	40.0	Shahan et al. (2020b)
Pigeons	59	29.5	Nighbor et al. (2020, Expt 1-3)
University Students	38	19.0	Podlesnik et al. (2020)
Children	9	4.5	Shvarts et al. (2020, Expt 2)
Zebrafish	3	1.5	Kuroda et al. (2020, Expt 1)
Nonstudent Adults	2	1.0	McHugh et al. (2012)
Monkeys	2	1.0	Mulick et al. (1976, Expt 1-2)
Mice	2	1.0	Craig et al. (2020, Expt 1-2)
Betta Splendens	1	0.5	da Silva et al. (2014)
Hens	1	0.5	Cleland et al. (2020)
Hen Chicks	1	0.5	Moriyama et al. (2015)
Crowdsourcing Adults	1	0.5	Robinson & Kelley (2020)
Adult Students	1	0.5	Dube et al. (2017)

Table 2. Search Results by Design and Participant

Design	Participants	Studies
Between subjects	Human	(Bolívar & Dallery, 2020), (Cox et al., 2019), (Okouchi, 2015), (Pittenger et al., 1988), (Reed, 2019), (Reed & Clark, 2011), (Smith et al., 2017), (Thrailkill et al., 2019)
Between subjects	Nonhuman	(Bouton & Schepers, 2014), (Bouton & Trask, 2016), (Brown et al., 2020), (Craig et al., 2017), (Craig et al., 2016), (Craig & Shahan, 2016), (Enkema et al., 1972), (Frye et al., 2018), (Galizio et al., 2018), (Hernandez et al., 2020), (Kestner et al., 2015), (Leitenberg et al., 1970), (Leitenberg et al., 1975), (Liddon et al., 2017), (Lieving & Lattal, 2003), (Moriyama et al., 2015), (Nakajima et al., 2002), (Nall et al., 2018), (Oliver et al., 2018), (Pacitti & Smith, 1977), (Pyszczynski & Shahan, 2014), (Rawson et al., 1977), (Sánchez-Carrasco & Nieto, 2011), (Schepers & Bouton, 2015), (Shahan et al., 2020a), (Sweeney & Shahan, 2013b), (Sweeney & Shahan, 2015), (Trask et al., 2018), (Winterbauer & Bouton, 2010), (Winterbauer & Bouton, 2011), (Winterbauer & Bouton, 2012), (Winterbauer et al., 2013)
Combo	Human	(Dixon & Hayes, 1998), (King & Hayes, 2016), (McHugh et al., 2012), (St. Peter Pipkin et al., 2010), (Podlesnik et al., 2020), (Sweeney et al., 2014)
Combo	Nonhuman	(Bouton & Trask, 2016), (Cook et al., 2020), (Kearns & Weiss, 2007), (Leitenberg et al., 1970), (Leitenberg et al., 1975), (Podlesnik & Kelley, 2014), (Quick et al., 2011), (Rawson & Leitenberg, 1973), (Reed & Morgan, 2007), (Shahan et al., 2020b), (Trask, 2019), (Trask & Bouton, 2016)
Other	Human	(Bolívar et al., 2017), (Sweeney & Shahan, 2016)
Within subjects	Human	(Alessandri & Cançado, 2020), (Alessandri et al., 2015), (Benavides & Escobar, 2017), (Bruzek et al., 2009), (Diaz-Salvat et al., 2020), (Doughty et al., 2010), (Doughty et al., 2011), (Doughty et al., 2014), (Galizio et al., 2020), (Garner et al., 2018), (Ho et al., 2018), (Houchins et al., 2022), (Kestner et al., 2018a), (Kestner et al., 2018b), (Kimball et al., 2018), (Kuroda et al., 2016), (Lambert et al., 2015), (Liggett et al., 2018), (Marsteller & St. Peter, 2012), (Podlesnik et al., 2019), (Robinson & Kelley, 2020), (Romano & St. Peter, 2017), (Shvarts et al., 2020), (Williams & St. Peter, 2020), (Wilson et al., 2016), (Wilson & Hayes, 1996)
Within subjects	Nonhuman	(Bachá-Méndez et al., 2007), (Bai et al., 2017), (Cançado et al., 2015), (Cançado & Lattal, 2013), (Cançado & Lattal, 2011), (Cleland et al., 2000), (Cook & Lattal, 2019), (Cook et al., 2020), (Craig et al., 2020), (Craig et al., 2018), (da Silva et al., 2014), (da Silva et al., 2008), (Doughty et al., 2007), (Dube et al., 2017), (Elcoro et al., 2019), (Epstein, 1983), (Fontes et al., 2018), (Fujimaki et al., 2015), (Ho et al., 2018), (Jarmolowicz & Lattal, 2014), (Kincaid et al., 2015), (Kincaid & Lattal, 2018), (Kuroda et al., 2020), (Kuroda et al., 2017b), (Lattal et al., 2019), (Liddon et al., 2017), (Lieving & Lattal, 2003), (Mulick et al., 1976), (Nevin et al., 2016), (Nighbor et al., 2020), (Nighbor et al., 2018), (Oliver et al., 2018), (Podlesnik et al., 2019), (Podlesnik et al., 2006), (Podlesnik & Shahan, 2009), (Podlesnik & Shahan, 2010), (Pyszczynski & Shahan, 2013), (Reed & Morgan, 2006), (Shahan et al., 2015), (Shvarts et al., 2020), (Sweeney et al., 2014), (Sweeney & Shahan, 2013a), (Thrailkill & Shahan, 2012), (Trask, 2019), (Trask & Bouton, 2016), (Trask et al., 2018), (Winterbauer & Bouton, 2011)

Table 3. Experiments Per Article.

Number of Experiments	Count	Percentage	Examples
1	120	60.0	Galizio et al. (2020)
2	49	24.5	Craig et al. (2020)
3	20	10.0	Diaz-Salvat et al. (2020)
4	7	3.5	Trask (2019)
5	3	1.5	Doughty et al. (2007)
6	1	0.5	Cançado et al. (2013)

Table 4. Groups Per Experiment.

Number of Groups	Count	Percentage	Examples
1	119	59.5	Houchins et al. (2020)
2	27	13.5	Brown et al. (2020, Expt 2)
3	25	12.5	Bolívar & Dallery (2020)
4	24	12.0	King & Hayes (2016)
5	1	0.5	Dixon & Hayes (1998)
6	2	1.0	Shahan et al. (2020a)
7	0	0.0	--
8	1	0.5	Pittenger et al. (1988, Expt 1)
9	0	0.0	--
10	1	0.5	Shahan et al. (2020b)

Table 5. Session Arrangement During Experiments.

Session Arrangement	Count	Percentage	Examples
≥1 per day, multiple days	166	83.0	Hernandez et al. 2020 (Expt 1-2)Hernandez et al. 2020 (Expt 1-2)
Single visit	24	12.0	Reed (2019)
≥1 per day, single day	10	5.0	Houchins et al. (2020)

Table 6. Testing Arrangement During Experiments.

Testing Arrangement	Count	Percentage	Examples
Multiple Data Points	159	79.5	Podlesnik et al. (2020)
Single Data Point	41	20.5	Galizio et al. (2020)

Table 7. Testing Arrangement During Experiments.

	Fixed		Performance Based	
Phase	Count	Percentage	Count	Percentage
Training	122	61.0	76	38.0
Elimination	132	66.0	68	34.0
Testing	159	79.5	41	20.5

Table 8. Experimental Designs.

Design	Variation	Count	Percentage	Examples
WS Designs	Total	115	57.5	--
None	Total	89	44.5	--
	BS Design	61	30.5	Thrailkill et al. (2020, Expt 1-2)
	Demonstration	26	13.0	Kincaid et al. (2018, Expt 1)
	Inductive Design	2	1.0	Sweeney & Shahan (2016)
Multiple Assessments (WS)	Total	45	22.5	--
	Multiple Assessment Only	35	17.5	Kestner et al., 2018a)
	Combined WS and BS Designs	10	5.0	Shahan et al. (2020b)
Phase Replications (WS)	Total	48	24.0	--
	Training, Elimination, Testing	28	14.0	Cook et al. (2020, Expt 1)
	Elimination, Testing	9	4.5	Liggett et al. (2018)
	Training, Elimination	6	3.0	Ho et al. (2018, Expt 1-2)
	Training, Testing	4	2.0	Fujimaki et al. (2015, Expt 1)
	ABCDABCABC design	1	0.5	Fontes et al. (2018)
Multiple Schedule (WS)	Total	30	15.0	--
	Multiple Schedule Only	20	10.0	Cançado & Lattal (2011)
	Combined WS and BS Designs	10	5.0	Reed & Morgan (2007, Expt 1-2)
Multiple Approaches (WS)	Total	26	13.0	--
	WS Designs Only	25	12.5	Houchins et al. (2020)
	Combined WS and BS Designs	1	0.5	St. Peter Pipkin et al. (2010, Expt 1)
Multiple Responses (WS)	Total	8	4.0	--
	Multiple Responses Only	7	3.5	Bruzek et al. (2009, Expt 2)
	Combined WS and BS Designs	1	0.5	King & Hayes (2016)
Concurrent Schedule (WS)	Total	2	1.0	Nighbor et al. (2018 Expt 2)
BS Designs	Total	61	30.0	--
	Group Designs	57	29.0	Winterbauer & Bouton (2010, Expt 1-4)
	Individual Response Patterns	4	2.0	Oliver et al. (2018, Expt 2ab)
Combinations of Designs	Total	22	11.0	Nevin et al. (2016, Expt 1)
Inductive Design	Total	2	1.0	Bolívar et al. (2017)

Note. Table presents both within-subjects (WS) and between-subjects (BS) designs.

Table 9. Direct Replications of Phases.

Phase Replication	Count	Percentage	Examples
Total	49	24.5	--
All Phases	29	14.5	Cook et al. (2020, Expt 1)
Elim & Test	10	5.0	Liggett et al. (2018)
Training & Elim	5	2.5	Ho et al. (2018, Expt 1-2)
Training & Test	4	2.0	Fujimaki et al. (2015, Expt 1)
ABCDABCABC design	1	0.5	Fontes et al. (2018)

Table 10. Types of Resurgence Tests.

Resurgence Testing	Count	Percentage	Examples
Extinction Only	165	82.5	Hernandez et al. (2020, Expt 1-2)
Comparisons	29	14.5	Oliver et al. (2019, Expt 1-2)
Non-Extinction Only	6	3.0	Bachá-Méndez et al. (2007, Expt 1-2)

Table 11. Types of Mitigation Techniques.

Mitigation Technique	Count	Percentage	Examples
Total	64	32.0	--
Thinning/Decreased SR	16	8.0	Trask & Bouton (2016, Expt 3)
Treatment Cues	14	7.0	Shvarts et al. (2020, Expt 1-2)
Response-Independent SR	8	4.0	Trask et al. (2018, Expt 2)
Punishment	7	3.5	Kestner et al. (2015)
Extended Elimination	6	3.0	Hernandez et al. (2020, Expt 1-2)
Multiple Alternatives	3	1.5	Lambert et al. (2015)
Drug Effects	3	1.5	Cook et al. (2020, Expt 2)
On/Off Contingencies	3	1.5	Trask et al. (2018, Expt 1)
Abstinence Contingency	2	1.0	Bouton & Schepers, 2014 (Expt 1-2)
Multiple Approaches	2	1.0	Shahan et al. (2020a)

Table 12. Control Conditions.

Control Condition	Variation	Count	Percentage	Examples
Inactive Control Responses	--	73	36.5	--
	One Inactive Response	46	23.0	Craig et al., 2020 (Expt 1-2)
	Multiple Inactive Responses	18	9.0	Galizio et al. (2020)
	Comparisons	4	2.0	Diaz-Salvat et al. (2020, Expt 2-3)
	Emotional/Other Responses	3	1.5	Liggett et al. (2018)
Typical Resurgence Procedure	--	61	30.5	Kuroda et al. (2020, Expt 2)
No Alt SR During Elimination	--	27	13.5	Sweeney & Shahan (2013a)
Omission of Training	--	6	3.0	da Silva et al. (2014)
Alt SR During Testing	--	1	0.5	Craig et al. (2017b)

Table 13. Comparison of Target- and Alternative-Response Topography.

Target vs. Alternative Topography	Count	Percentage	Examples
Same	131	65.5	Galizio et al. (2020)
Different	60	30.0	Craig et al. (2020, Expt 1-2)
Alt Comparison	9	4.5	Sweeney et al. (2014, Expt 1-2)

Table 14. Number of Alternative Responses.

Number of Alternative Responses	Count	Percentage	Examples
One	154	77.0	Brown et al. (2020, Expt 2)
None	24	12.0	Alessandri & Cançado (2020)
Multiple	13	12.5	Diaz-Salvat et al. (2020, Expt 2)
Comparison	9	4.5	Diaz-Salvat et al. (2020, Expt 1,3)

Table 15. Number of Alternative Responses.

	Target		Alternative		Control	
Response Topography	Count	Percentage	Count	Percentage	Count	Percentage
Manipulandum	151	75.5	105	52.5	47	23.5
Computer Screen	27	13.5	26	13.0	12	6.0
Keyboard	8	4.0	5	2.5	4	2.0
Activity	7	3.5	10	5.0	4	2.0
Sensor	4	2.0	20	10.0	3	1.5
Combination	2	1.0	2	1.0	--	--
Other	1	0.5	1	0.5	--	--
None	0	0.0	23	11.5	127	63.5
Comparison	0	0.0	8	4.0	--	--
Emotional/Other	--	--	--	--	3	1.5

Table 16. Availability of Alternative Responses During Training.

Alternative Response During Training	Count	Percentage	Examples
Present	75	37.5	Podlesnik et al., 2019 (Expt 2)
Comparison	3	1.5	Rawson et al. (1977, Expt 2)
Misc.	3	1.5	Williams & St. Peter (2020, Expt 1-2)

Table 17. Comparison of Target and Alternative Reinforcement Schedules.

Target vs. Alternative Reinforcement Schedules	Count	Percentage	Examples
Different	117	58.5	Galizio et al. (2020)
Same	61	30.5	Craig et al. (2020, Expt 1-2)
Comparison	22	11.0	Sweeney et al. (2014, Expt 1-2)

Table 18. Comparison of Target and Alternative Reinforcement Schedules.

	Target		Alternative	
Reinforcement Schedule	Count	Percentage	Count	Percentage
Partial Reinforcement	145	72.5	79	39.5
Comparison	27	13.5	73	36.5
Continuous Reinforcement	16	8	23	11.5
Combination	6	3	4	2
Duration	2	1	2	1
Relative Frequency	1	0.5	1	0.5
Other	1	0.5	1	0.5
Progressive Ratio	1	0.5	0	0
Dependent + Independent	1	0.5	0	0
Omission Schedule	0	0	11	5.5
Response Independent	0	0	4	2
Lag Schedule	0	0	1	0.5
Activity	0	0	1	0.5

Table 19. Other Characteristics of Response-Reinforcer Contingencies.

Other Schedule Characteristics	Count	Percentage	Examples
Free-Operant Contingency	179	89.5	Houchins et al. (2021)
Discrete-Trial Procedure	21	10.5	Doughty et al. (2010)
Changeover Requirement	60	30.0	Podlesnik et al. (2020)
Response Sequences	11	5.5	Galizio et al. (2018, Expt 3)

Table 20. Deceleration Procedures Arranged during Elimination.

Deceleration Procedures	Count	Percentage	Examples
Response Dependent + Extinction (DRA)	122	61.0	Williams & St. Peter (2020, Expt 1-2)
Comparison	40	20.0	Kestner et al. (2018)
Omission (DRO)	18	9.0	Nighbor et al. (2018, Expt 1-2)
Different Sequence	6	3.0	Galizio et al. (2018, Expt 4)
Response Independent + Extinction (NCR)	5	2.5	Trask & Bouton, 2016 (Expt 1-3)
Extinction	3	1.5	Reed & Clark (2011)
Between-Component DRA	2	1.0	Pyszczynski & Shahan (2013, Expt 1-2)
Different Duration	1	0.5	Benavides & Escobar (2017)

Table 21. Deceleration Procedures Arranged during Elimination.

Target vs. Alternative Reinforcer Type	Count	Percentage	Examples
Same	170	85.0	Diaz-Salvat et al. (2020, Expt 1-3)
Different	26	13.0	Cook et al. (2020, Expt 1-2)
Comparison	1	0.5	Craig et al. (2018)

Table 22. Deceleration Procedures Arranged during Elimination.

	Target		Alternative	
Reinforcement Type	Count	Percentage	Count	Percentage
Edible	137	68.5	151	75.5
Points	22	11.0	22	11.0
Drug	12	6.0	0	0.0
Performance Feedback	8	4.0	8	4.0
Combination	5	2.5	4	2.0
Comparison	5	2.5	2	1.0
Escape/Avoid	4	2.0	4	2.0
Token	3	1.5	4	2.0
Stimulus	2	1.0	2	1.0
Automatic	1	0.5	1	0.5
Edible or Activity	1	0.5	1	0.5
Activity	0	0.0	1	0.5

Table 23. Type of Backup Reinforcer.

	Target		Alternative	
Backup-Reinforcer Type	Count	Percentage	Count	Percentage
Total	21	10.5	19	9.5
Money	10	5	10	5
Edible	5	2.5	3	1.5
Gift-Card Lottery	3	1.5	3	1.5
Money Lottery	2	1	2	1
Unspecified Items	1	0.5	1	0.5

Table 24. Availability of Course Credit for Participation.

Course Credit	Count	Percentage	Examples
Total	26	13.0	--
Time Contingent Only	21	10.5	Bolívar & Dallery (2020)
Time Contingent + Contingent Backup Reinforcers	5	2.5	Podlesnik et al. (2020)

Table 25. Availability of Course Credit for Participation.

Punishment	Count	Percentage	Examples
Total	9	4.5	--
Shock	4	2.0	Rawson & Leitenberg (1973)
Response Cost	3	1.5	Okouchi (2015)
Negative Performance Feedback	1	0.5	Wilson & Hayes (1996)
Timeout	1	0.5	Houchins et al. (2021)

Table 26. Criteria Used to Define a Resurgence Effect.

Definitions	Count	Percentage	Examples
Unspecified Criteria	67	33.5	Nighbor et al. (2020, Expt 1-3)
Last Elim vs. First Test	49	24.5	Galizio et al. (2020)
Greater than Control Responding	40	20.0	Craig et al. (2020, Expt 1-2)
Last Elim vs. Multiple Test	39	19.5	Kuroda et al. (2020, Expt 1)
Multiple Elim vs. Multiple Test	34	17.0	Diaz-Salvat et al. (2020, Expt 1-3)
Compare with Control Group/Assessment	20	10.0	Trask et al. (2018, Expt 2)
Greater than Alternative Responding	5	2.5	Doughty et al. (2014, Expt 1-2)
Elim Test vs. Resurgence Test	4	2.0	Trask & Bouton (2016, Expt 1-3)
Statistically Greater than Chance	3	1.5	Reed & Morgan (2006)
Target Responding ≥ 1	2	1.0	Williams & St. Peter (2020, Expt 1-2)
Last Elim vs. Highest Test	2	1.0	Cook et al. (2020, Expt 1-2)

Table 27. Type of General Analytic Strategy Used to Evaluate Resurgence Effects.

General Analytic Strategy	Count	Percentage	Examples
Individual-Subject Analysis	121	60.5	Elcoro et al. (2019)
NHST	107	53.5	Hernandez et al. (2020, Expt 1-2)
NHST and Individual-Subject Analysis	29	14.5	Cox et al. (2019)
Mixed-Effects Modeling	1	0.5	Frye et al. (2018)

Table 28. Direct Measures Used to Assess Resurgence.

Direct Measures	Count	Percentage	Examples
Total	180	90.0	--
Rate or Count	168	84.0	Nighbor et al. (2020, Expt 1-3)
Cumulative Responses	20	10.0	Shahan et al. (2015)
Intervals Including a Target Response	2	1.0	Cook & Lattal, 2019 (Expt 1-2)
Latency	2	1.0	Frye et al. (2018)
Response Switches/Changeovers	2	1.0	Elcoro et al. (2019)
Duration	1	0.5	Benavides & Escobar (2017)
Prevalence Count	1	0.5	Galizio et al. (2020)

Table 29. Derived Measures Used to Assess Resurgence.

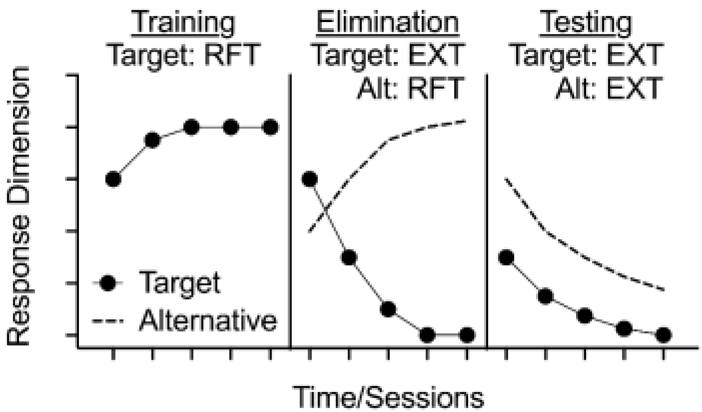
Derived Measures	Count	Percentage	Examples
Total	65	32.5	--
Proportion/% of Training Responding	34	17.0	Podlesnik et al. (2020)
Difference from Elim Responding	15	7.5	Ho et al. (2018, Expt 1-2)
Proportion/% of Total Responding	13	6.5	Brown et al. (2020, Expt 2)
Proportion/% of Elim Responding	10	5.0	Reed (2019)
f(SR) Rate/Distribution	5	2.5	Shahan et al. (2020b)
Difference Between Proportions of Training	2	1.0	Sweeney et al. (2014, Expt 1-2)
Correlation	2	1.0	Frye et al. (2018)
U-Value	2	1.0	Galizio et al. (2020)
Proportion of Opportunities	1	0.5	Elcoro et al. (2019)
Percentage of Force Criterion	1	0.5	Alessandri et al. (2015, Expt 1)
Proportion of Sequences Meeting Lag Contingency	1	0.5	Galizio et al. (2018, Expt 4)

Table 30. Quantitative Theoretical Frameworks Employed in Resurgence Experiments.

	Simulation		Model Fit	
Theoretical Framework	Count	Percentage	Count	Percentage
Behavioral Momentum Theory	3	1.5	10	5.0
Resurgence as Choice	1	0.5	2	1.0
Stimulus-Control Model	0	0.0	1	0.5

Figures

Figure 1. Hypothetical data across phases of a resurgence procedure



Note. Target and alternative (alt) responses produce either reinforcement (RFT) or extinction (EXT) across Training, Elimination, and Testing.

Figure 2. Flow chart of review

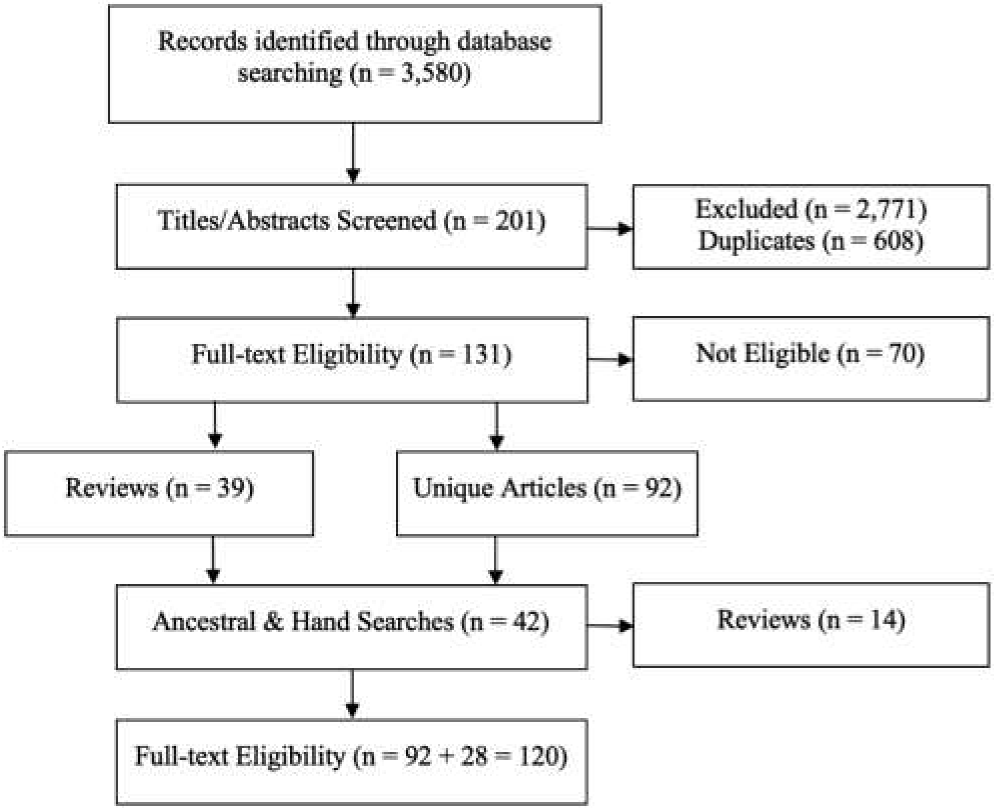


Figure 3. Counts of articles shown cumulatively and per year

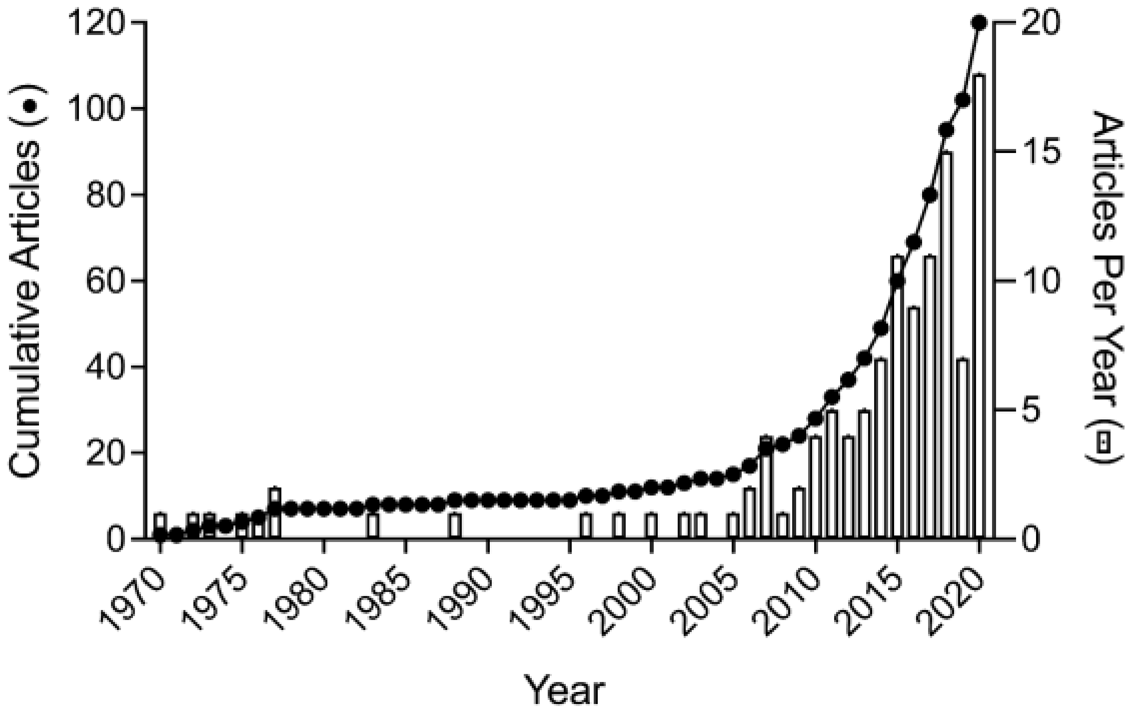


Figure 4. Counts of articles across journals

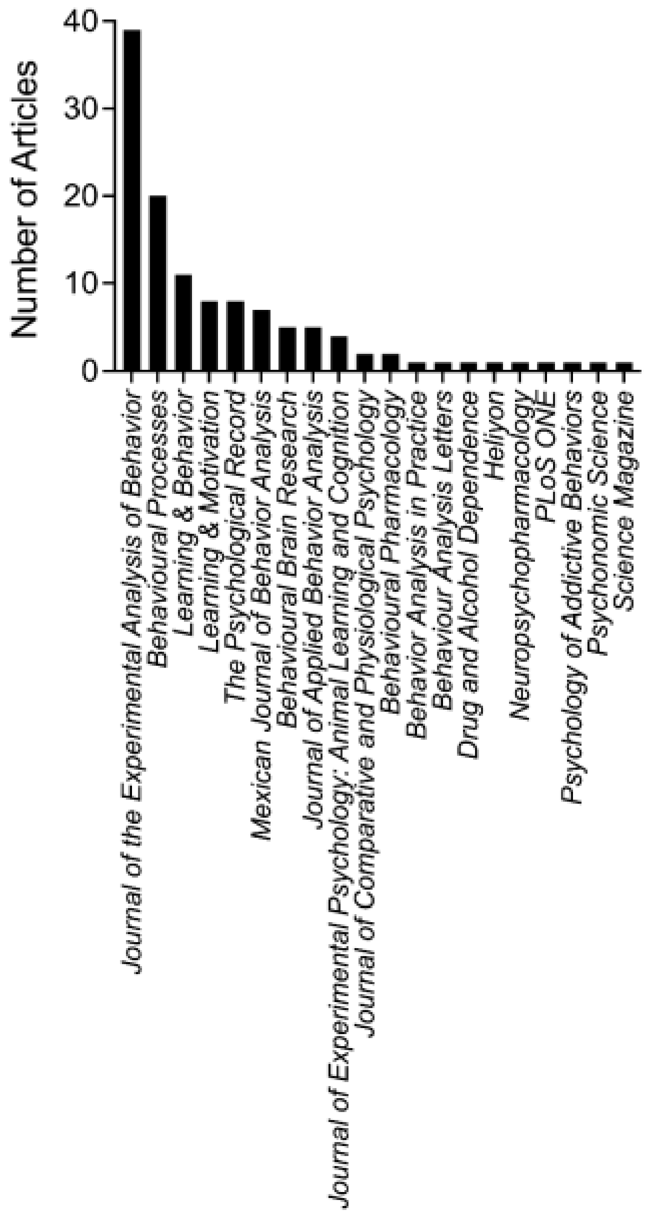


Figure 5. Counts of experiments employing different populations of participants