

# Extinction training can make the extinction context a stimulus-specific inhibitor: A potential mechanism of experimental renewal



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## ARTICLE INFO

### Keywords:

Extinction  
Renewal  
Conditioned inhibition  
Stimulus-specific inhibition

## ABSTRACT

Renewal is the recovery of extinguished responding to a conditioned stimulus when testing occurs outside the extinction context. Renewal has been explained as the extinction context becoming a negative occasion setter during extinction. However, other mechanisms may contribute. Two recent studies showed (a) after extinction of a discrete cue, the extinction context can serve as a conditioned inhibitor, and (b) in some circumstances operational extinction of a conditioned inhibitor can reduce inhibition with respect to a transfer excitator while retaining inhibition with respect to the excitator used in inhibitory training. Here we examine the potential contribution of these phenomena to renewal. In the present experiment, all rats received fear-conditioning with a target cue in one context and extinction of that cue in a second context. Then half of the subjects received massive extinction of the extinction context (i.e., 24 h) while the other half received only handling. Finally, some subjects in each condition were tested for responding to the target cue in the extinction context, others in a second familiar context, and yet others in a third transfer context in which another fear cue had been extinguished. The results showed ABC renewal independent of whether subjects had or had not received context extinction. However, transfer of the inhibitory potential of the extinction context was observed only in subjects that did not receive context extinction. These results suggest an extinction context can serve as a stimulus-specific conditioned inhibitor, thereby contributing to renewal by decreasing responding to the target cue in an ABB control condition.

## 1. Introduction

In a review of the extinction literature, Rescorla (2004) described how the term *extinction* has been used in the associative literature in three different ways. For Rescorla, extinction can denote (a) an experimental operation or independent variable (e.g., nonreinforced presentations of a conditioned stimulus [CS]), (b) a behavioral effect or dependent variable (e.g., a decrease in conditioned responding to the CS), or (c) a process or intervening variable underlying the behavioral effect of the extinction operation (e.g., decreased responding because of an *extinction process*, such as associative weakening, produced by nonreinforced presentations of the CS). More recently, Nelson, Sanjuan, Vadillo-Ruiz, Pérez, and León (2011) presented a similar analysis of the term *renewal*. For them, renewal can denote an empirical manipulation (i.e., ABA, ABC, and AAB renewal designs), a behavioral effect or result (i.e., recovery of extinguished responding when testing occurs outside of the extinction context), or a mechanism that explains the behavioral effect of a renewal design (e.g., modulation of responding to the CS by the context in which it was extinguished). However,

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<https://doi.org/10.1016/j.lmot.2020.101623>

Received 22 September 2019; Received in revised form 21 January 2020; Accepted 20 February 2020

Available online 18 March 2020

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unlike Rescorla's analysis of the term extinction, Nelson et al. proposed to constrain the definition of renewal to the specific mechanism, down modulation of the CS-outcome association by the extinction context, suggested by Bouton (e.g., 1993), categorically ruling out any other potential mechanism as contributing to the renewal effect (e.g., Cases B-D in Nelson et al.'s Fig. 1). In Nelson et al.'s words:

"We observed a recovery of responding to an extinguished CS in a neutral context, where recovery could not be due to the test context serving any role as a simple CS, and that there was no inhibition conditioned to the extinction context... The recovery was not due to losing or gaining information about the US controlled by the contexts directly. *That is, renewal was observed* [italics added] (p. 68)."

We strongly reject such a constraint because it (a) forecloses on experimental analysis of the processes underlying behavioral renewal, and (b) categorically precludes consideration of behavioral renewal arising from multiple mechanisms. In our view, the use of the term *renewal* should not presume the mechanism of a given phenomenon (e.g., contextual modulation of extinction). Instead, we suggest that our understanding of the phenomenon would best be served by regarding *renewal* to be a specific behavioral result of a specific operational treatment, and not be restricted to one specific presumed underlying mechanism. More generally, the names of behavioral phenomena should refer to the operations that produce the phenomena or the empirical phenomena, not to one of the presumed underlying mechanisms. Past failures to adhere to this rule have given us misnomers such as *latent inhibition* (Lubow & Moore, 1959), which still continues to bedevil students. Empirically, renewal can be defined as a recovery of conditioned responding after a shift in context away from the context of extinction. Mechanistically, multiple sources of recovery likely contribute to renewal. Motivated by results from previous reports from our laboratory (Polack, Laborda, & Miller, 2012; Polack, Laborda, & Miller, 2019), here we present a new experiment in which we evaluated the potential of the context of extinction to function as a stimulus-specific conditioned inhibitor, thereby serving as one of likely many sources of the renewal effect.

Stimulus-specific conditioned inhibition by the extinction context as one alternative mechanism of renewal is supported by two recent studies. First, Polack et al. (2012) reported a series of experiments in which a context became inhibitory through extinction of an excitatory CS, a result that has eluded other researchers (e.g., Bouton & King, 1983; Nelson et al., 2011). Critically, trial spacing proved to be negatively related to contextual conditioned inhibition (i.e., more behavior indicative of inhibition was evidenced with massed than with spaced extinction trials), as indexed by summation and retardation tests. Thus, Polack et al.'s results (2012) suggest that, at least with certain parameters, extinction of a discrete excitator in a context different from that of acquisition training can cause the extinction context to acquire inhibitory properties. Considering that contextual conditioned inhibition was stronger when extinction treatment was massed, it is possible that during extinction treatment with relatively long intertrial intervals (ITIs; as was the case in most renewal studies that have failed to detect inhibitory properties in extinction contexts; e.g., Bouton & King, 1983), the inhibitory properties of the context extinguished thereby preventing researchers from detecting inhibitory effects as is predicted by the Rescorla and Wagner (1972) model. However, previous attempts to reduce conditioned inhibition through posttraining exposure to the conditioned inhibitor have failed to produce a reduction in inhibition (e.g., Williams, Overmier, & LoLordo, 1992; Zimmer-Hart & Rescorla, 1974).

Second, Polack et al. (2019) evaluated whether under certain condition posttraining exposure of a discrete inhibitor could actually reduce conditioned inhibition. Despite several prior failures to observe such an effect (e.g., Williams et al., 1992; Zimmer-Hart & Rescorla, 1974), possibly the designs of prior experiments simply were not sufficiently sensitive to detect it. To assess this possibility, Polack et al. (2019) evaluated whether using massive posttraining exposure to a conditioned inhibitor (i.e., 300 30-s presentations) might facilitate the observation of reduced inhibition. Consistent with the possibility that such massive amounts of extinction treatment can reduce conditioned inhibition, the authors found that massive exposure to a discrete conditioned inhibitor reduced its inhibitory properties as measured using summation and retardation tests. However, this extinction of a conditioned inhibitor was seen to attenuate inhibition only with respect to a negative summation test with a transfer stimulus and did not influence summation with the original training excitator. This observation indicates that extinction of a conditioned inhibitor does not completely eliminate inhibitory control, but rather makes it more stimulus specific. The inhibitory status of the massively extinguished conditioned inhibitor was evident only if it was tested with the excitator with which it was previously trained during Pavlovian inhibition treatment (i.e., Y-US/YX-). Thus, after extinction of a conditioned inhibitor, its influence is no longer as general as is commonly observed with conditioned inhibitors.

Together, Polack et al.'s experiments (2012, 2019) suggest a potential explanation of why others (e.g., Bouton & King, 1983; Nelson et al., 2011) did not observe indicators of contextual conditioned inhibition in their renewal studies. Also, this account can be seen as an extension and elaboration of other accounts of renewal based on contextual conditioned inhibition (e.g., Rescorla & Wagner, 1972). It is possible that in certain cases the context of extinction becomes a functional conditioned inhibitor during extinction training. Then, exposure to the context in which CS extinction occurred selectively decreases the potential of the inhibitory context to inhibit responding to a transfer stimulus, while still negatively summing with the excitator (i.e., the CS) used during the putative contextual inhibitory training (i.e., CS extinction treatment). In the following experiment, we directly tested this potential mechanism as one (of several) processes that can contribute to the behavioral phenomenon of renewal.

The present experiment evaluated whether an extinction context becoming a stimulus-specific conditioned inhibitor provides a realistic account of at least some instances of renewal. We have previously demonstrated that an extinction context can become inhibitory when exposure to the extinction context is limited (e.g., through massed presentations of extinction trials; Polack et al., 2012). We here refer to an extinguished conditioned inhibitor as being 'stimulus-specific' because it selectively attenuates responding to the original training excitator (Polack et al., 2019). The present experiment tests whether extinction of an inhibitory context results in similar stimulus-specific inhibition. Assuming the extinction context has inhibitory value, observation of stimulus-specific

contextual inhibition would be consistent with the conventional behavioral definition of renewal.

To evaluate this possibility, rats first received acquisition training of two distinct cues in two different contexts (i.e., [X + ]<sub>A</sub> and [Y + ]<sub>E</sub>). Then, both cues received extinction treatment in yet another two contexts (i.e., [X - ]<sub>B</sub>, [Y - ]<sub>D</sub>) and equal exposure to a fifth context (i.e., [- ]<sub>C</sub>). Before testing the target cue in the context in which it was extinguished (i.e., [X]<sub>B</sub>), in a neutral but familiar context (i.e., [X]<sub>C</sub>), and in the context in which the other excitor was extinguished (i.e., [X]<sub>D</sub>), half of the rats received massive exposure to all three contexts, while the other half was just handled. Parameters were explicitly selected to favor demonstrating a role of conditioned inhibition in renewal under at least some conditions.

## 2. Method

### 2.1. Subjects

Subjects were 36 male and 36 female, experimentally naive, Sprague-Dawley descended rats obtained from our own breeding colony. Body-weight ranges were 299–415 g for males and 211–278 g for females. Subjects were randomly assigned to one of six groups ( $n_s = 12$ ; ABB-NoCtxExp, ABC-NoCtxExp, Transf-NoCtxExp, ABB-CtxExp, ABC-CtxExp, and Transf-CtxExp), counterbalanced within groups for sex. The animals were individually housed in standard hanging stainless-steel wire-mesh cages in a vivarium maintained on a 16/8-hr light/dark cycle. Experimental manipulations occurred near the middle portion of the light phase. The animals received free access to Purina Lab Chow, whereas water availability was limited to 30 min per day following a progressive deprivation schedule initiated one week prior to the start of the study. From the time of weaning until the start of the study, all animals were handled for 30 s, three times per week.

### 2.2. Apparatus

Thirty-six experimental chambers, of three different types, were used. Chamber O was 30-cm long, 30-cm wide, and 27-cm high. The sidewalls of the chamber were made of stainless steel sheet metal, and the front wall, back wall, and ceiling of the chamber were made of clear Plexiglas. The floor was constructed of 0.3 cm diameter rods, spaced 1.3 cm center-to-center, and connected by NE-2 neon bulbs that allowed a 0.7-mA, 0.5-s constant-current footshock to be delivered by means of a high voltage AC circuit in series with a 1.0-M $\Omega$  resistor. Each of twelve copies of Chamber O was housed in an environmental isolation chest that was dimly illuminated by a house light (1.12-Watt, #1820 incandescent bulb) mounted on the left wall of the experimental chamber.

Chamber R was rectangular, measuring 24.0  $\times$  9.0  $\times$  12.5-cm (l  $\times$  w  $\times$  h). The walls and ceiling were clear Plexiglas, and the floor comprised of stainless steel rods measuring 0.5-cm diameter, spaced 1.3-cm apart (center-to-center). The rods were connected by NE-2 bulbs, which allowed for the delivery a 0.7-mA, 0.5-s constant current footshock. Each of twelve copies of Chamber R was housed in separate light- and sound-attenuating environmental isolation chambers. Each chamber was dimly illuminated by a 2-W (nominal at 120 VAC, but driven at 50 VAC) incandescent house light mounted on an inside wall of the environmental chest located approximately 30-cm from the center of animal enclosure.

Chamber V was 27-cm long, 29.5-cm high, 21.5-cm wide at the top, and 5.5-cm wide at the bottom. The floor was comprised of two 27-cm long plates, 2-cm wide, with a 1.5-cm gap between the two plates. A 0.7-mA, 0.5-s constant-current footshock could be delivered through the metal walls and floor of the chamber. The ceiling was clear Plexiglas, the front and back walls were black Plexiglas, and the sidewalls were stainless steel. Each of twelve copies of Chamber V was housed in a separate sound- and light-attenuating environmental isolation chest. The chamber was illuminated by a 7-W (nominal at 120 VAC, but driven at 60 VAC) light bulb, which was mounted on the inside wall of the environmental enclosure, approximately 30-cm from the center of the experimental chamber. The light entered the chamber primarily by reflection from the ceiling of the environmental chest.

All chambers could be equipped with a water-filled lick tube that extended 1-cm into a cylindrical niche, which was 4.5-cm in diameter, left right centered, with its bottom 1.75-cm above the floor of the apparatus and 5.0-cm deep. In all chambers there was a photobeam detector 1-cm in front of the lick tube that was broken whenever the subject licked the tube. Two 45-W speakers on the inside and back walls of the isolation chests of all types of chambers used could deliver a click train (6 Hz) and white noise at 6 dB(C) above background. These stimuli served as cues X and Y (counterbalanced within group) and were 30-s in duration. Ventilation fans in each enclosure provided a constant 76-dB(C) background noise. The 0.5-sec footshock served as the US. The light intensities inside the three chambers were approximately equal due to the differences in opaqueness of the walls.

Five physical contexts were used in this study, two for acquisition training (Contexts A and E), and three for extinction treatment and testing (Contexts B, C, and D). The physical contexts used as Context A and E were counterbalanced within groups, and were: (1) an instance of Chamber O with the house light (HL) off and an odor present provided by a block of wood with two drops of 98 % methyl salicylate on it, and (2) an instance of Chamber R with the HL off and a different odor present provided by a block of wood with two drops of anise essence on it. The physical contexts used as Context B, C, and D were also counterbalanced within groups, and they were: (3) an instance of Chamber O (different from the one used as [1]) with the HL on and no odor cue present, (4) an instance of Chamber R (different from the one used as [2]) with the HL on and no odor cue present, and (5) an instance of Chamber V with the HL on and no odor cue present.

### 2.3. Procedures

See Table 1 for the experimental design. On Day 1, all subjects were acclimated to Contexts B, C, and D each for 30 min with a 2-h

**Table 1**  
Design Summary.

Groups	Acquisition Training	Extinction Treatment	Context Exposure	Summation Test
ABB-NoCtxExp				(X) <sub>B</sub>
ABC-NoCtxExp			Handling	(X) <sub>C</sub>
Transf-NoCtxExp	360 min (24 X <sub>A</sub> ) <sub>A</sub>	24 min (40 X <sub>-</sub> ) <sub>B</sub>		(X) <sub>D</sub>
ABB-CtxExp	360 min (24 Y <sub>A</sub> ) <sub>E</sub>	24 min (-) <sub>C</sub>	12 h (-) <sub>B</sub>	(X) <sub>B</sub>
ABC-CtxExp		24 min (40 Y <sub>-</sub> ) <sub>D</sub>	12 h (-) <sub>C</sub>	(X) <sub>C</sub>
Transf-CtxExp			12 h (-) <sub>D</sub>	(X) <sub>D</sub>

*Note:* X and Y were a click train and a white noise, counterbalanced. Letters in subscript indicate contexts. Contexts A and E were counterbalanced. Contexts B, C, and D were counterbalanced. Numbers in parenthesis indicate the total number of trials during that phase. Numbers before the parentheses indicate the total time of context exposure in that phase.

interval between adjacent sessions. The order of context acclimation was counterbalanced within group. Subjects had access to water-filled lick tubes in all contexts. There were no presentations of either CSs or the US during this phase. At the end of acclimation, the water tubes were removed until testing.

On Days 2–5, all subjects received six daily presentations of CS X co-terminating with the US in a 90-min session in Context A. Stimulus onsets occurred at 4, 24, 39, 54, 64, and 79-min into the session for an average intertrial interval of 15 min (from CS onset to CS onset), including the entire session. Each day, all subjects also received an identical acquisition training session for CS Y in Context E. The order of X and Y training sessions within days was counterbalanced within groups.

On Days 6–9, all subjects received 10 nonreinforced presentations of CS X in Context B within a daily 6-min session with an intertrial interval of 36 s (from CS onset to CS onset), including the entire session. Additionally, subjects received identical extinction sessions with CS Y in Context D and equivalent exposure to Context C without any discrete stimulus being presented. The order of sessions within days was counterbalanced within groups.

On Days 10–13, subjects in Condition CtxExp received 180-min daily exposures to Contexts B, C, and D. The order of exposure to each context was consistent with the order of exposure on Days 6–9. Subjects in Condition NoCtxExp received equivalent handling, but no exposure to any of the contexts.

Prior to Day 14, the lick tubes were reinserted into Contexts B, C, and D. On Day 14, all subjects were test for conditioned lick suppression to the target cue X. Subjects in Condition ABB were tested in Context B, subjects in Condition ABC in Context C, and subjects in Condition Transf in Context D. Stimulus X was presented immediately as each subject was placed in its test context and continued throughout the session because we were interested in the reaction to the combined presentation of CS X and the test context. The rationale for this test procedure was to avoid subjects' reducing their attention to the context with increasing time on it on the test trial prior to onset of the CS. Subjects were tested one at a time to facilitate onset of CS X immediately upon placement into the test context. Time for each subject to complete 5 cumulative seconds of drinking after placement in the test context was recorded. The test had an upper limit of 15 min recorded for subjects that did not complete 5 cumulative seconds of drinking. Subjects were removed from their test chambers once they completed 5 cumulative seconds of drinking.

#### 2.4. Data analysis

Latencies to drink for 5 cumulative seconds after the onset of the test stimulus were transformed to log<sub>10</sub> to better approximate the normal distributions assumed by parametric statistical analyses. A factorial analysis of variance (ANOVA) was used to determine whether our manipulations affected subjects' log latencies to drink in the presence of the test stimuli. The error term from the ANOVA served as an estimate of within-group variance in planned comparisons. Effect size of the ANOVA was estimated using Cohen's *f* (Myers & Wells, 2003). Alpha was set at .05.

### 3. Results

The results of the present experiment are illustrated in Fig. 1. As expected, less responding was observed when subjects were tested with an extinguished CS in the context in which that particular CS was extinguished (i.e., ABB condition) than when subjects were tested in a familiar but associatively neutral context (i.e., ABC condition). This ABC renewal effect was evidenced independent of whether or not the context of extinction was subjected to extra exposure treatment after extinction of the training excitator (i.e., post-extinction exposure of the extinction context did not significantly affect the strength of ABC renewal; see also Laborda, Witnauer, & Miller, 2011). The present data, like Polack et al.'s results (2012, 2019), support the view that, at least under certain circumstances, the context of extinction can pass a summation test for conditioned inhibition when the excitatory CS from inhibition training is used to measure negative summation. More relevant to the present discussion, a context of extinction (D) also negatively summated with a transfer stimulus (X), but only when the subject was not extensively exposed to the extinction context following CS extinction. This pattern of results corroborates that a context of extinction can acquire inhibitory properties, and that post-extinction exposure of the extinction context (through direct exposure as in this experiment or during long intertrial intervals [5 h when summed across all CS extinction trials] as in Polack et al., 2012, 2019) renders these acquired inhibitory properties specific to the excitator extinguished in that context. These conclusions are supported by the following statistical analysis.

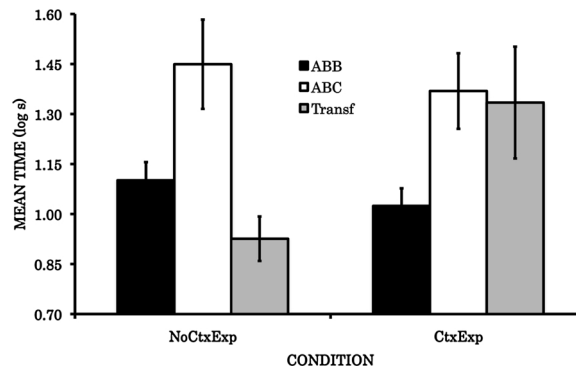


Fig. 1. Mean log time to complete five cumulative seconds of licking in the presence of the target CS (X) in Context B for Condition ABB, in Context C for Condition ABC, and in Context D for Condition Transf. The lowest possible score (i.e., 5 s to complete 5 s of drinking) corresponds to 0.70 log s. See Table 1 for treatments. Brackets represent SEMs. Higher scores indicate more conditioned suppression.

A three (context of testing: B vs. C vs. D) x two (context exposure: NoCtxExp vs. CtxExp) ANOVA conducted on log CS scores of the test day found a main effect of the context of testing,  $F(2, 66) = 5.86$ ,  $MSE = 0.14$ , Cohen's  $f = 0.37$ , and more importantly an interaction between the context of testing and context exposure,  $F(2, 66) = 3.44$ , Cohen's  $f = 0.26$ . The main effect of context exposure was not significant,  $p = .34$ . Planned comparisons were conducted to identify the sources of the observed interaction. First, the comparison between Groups ABB and ABC proved significant following post-extinction context exposure,  $F(1, 66) = 5.16$ , in addition to when such exposure was absent,  $F(1, 66) = 5.26$ , evidencing ABC renewal in both conditions. Second, the comparison between Groups ABC and Transf proved significant,  $F(1, 66) = 11.90$ , in the NoCtxExp condition, but not when the context was extensively exposed after CS extinction treatment,  $p = .82$ , suggesting that an extinguished CS negatively summates with a context in which a different excitator had been extinguished, but only if the context has not been later extinguished. This pattern of results is corroborated by a comparison of Groups Transf-CtxExp and Transf-NoCtxExp, which were found to differ,  $F(1, 66) = 7.25$ , supporting the view that the inhibitory properties of a context of extinction become CS specific if the context itself receives later exposure. The comparisons between Groups ABB-CtxExp and ABB-NoCtxExp, and between Groups ABC-CtxExp and ABC-NoCtxExp failed to prove significant, smallest  $p = .60$ . Additionally, the comparison between Groups ABB and Transf was significant in Condition CtxExp,  $F(1, 66) = 4.18$ , but not in Condition NoCtxExp,  $p = .25$ .

In summary, as indicated by the significant interaction between the context of testing and context exposure, the context of extinction negatively summated (i.e., passed a summation test for inhibition) with both the training excitator and a transfer stimulus. However, following post-extinction exposure to the extinction context, the inhibitory properties of the context became specific to the cue that was extinguished in it (i.e., the context of extinction became a stimulus-specific inhibitor).

### 4. Discussion

The results presented here strongly suggest that the associative status of an extinction context is one (of several) factors that can potentially contribute to the renewal effect. More specifically, the context in which extinction occurs can become a conditioned inhibitor (see Condition NoCtxExp in the above experiment; also Polack et al., 2012), and this inhibition can be extinguished with subsequent presentations of the context alone. Presumably, the same thing happens during the intertrial intervals of extinction treatment, which could explain why other researchers have not found extinction contexts to be inhibitory (e.g., Bouton & King, 1983;



Nelson et al., 2011). Centrally, this extinction of conditioned inhibition does not fully abolish the inhibitory properties of the extinction context, but it makes them specific to the training excitator (see Condition CtxExp in the above experiment; also Polack et al., 2019). Thus, when subjects are tested back in the context of extinction (ABB control), the context negatively summates with the target cue, producing a reduction in behavioral control in comparison to subjects that are tested in a neutral but familiar context (ABC renewal). One might interpret this as a case of an inhibitor becoming an occasion setter (e.g., Holland, 1983). However, the transfer stimulus was treated identically to the training excitator (note that in Nelson et al. (2011) the transfer stimulus was always reinforced), which should have supported transfer of occasion setting (e.g., Holland, 1989), but was not observed to occur. Also, if Context B serves as an occasion setter, mere exposure should not decrease its modulatory properties, as it did. Thus, this phenomenon of stimulus-specific inhibition appears to be even more stimulus specific than are occasion setters.

Together with Polack et al.'s reports (2012, 2019), the present data suggest that an extinction context becoming inhibitory is still a viable mechanism that can sometimes contribute to behavioral renewal. Importantly, these results also suggest an alternative explanation for those reports that failed to detect any inhibitory potential in their extinction contexts (e.g., Bouton & King, 1983; Nelson et al., 2011). During extinction treatment, their extinction contexts may have become stimulus-specific conditioned inhibitors, which we would expect, given the results presented here, to negatively summate exclusively with the training excitator. All this said, these results do not deny that occasion setting by the extinction context contributes to renewal under some circumstances. Instead, the present observations merely suggest that the context of extinction becoming a stimulus-specific inhibitor is a potential contributing factor in some instances of renewal (but see Trask, Thraillkill, & Bouton, 2017).

Although we view the present observation that extensive exposure to Context D (in which CS Y had been extinguished) resulted in more suppression to CS X than did extensive exposure to Context B (in which CS X had been extinguished) as evidence that extinction treatment made the extinction context a conditioned inhibitor specific to the CS extinguished in that context, there are other possible accounts. One is that extinction treatment made the extinction context a conventional conditioned inhibitor, and additionally configural learning during extinction treatment made XD (and YB) 'safe' stimuli for the subjects. These two mechanisms could account for the present observations but the account lacks parsimony in that it requires two processes occurring during extinction treatment. However, our preferred account of stimulus-specific inhibition calls for a theoretical foundation that we prefer not to speculate on at this time, but it too might well involve two different processes.

A second alternative account of the present observations completely circumvents positing that extinction imparts inhibitory properties to the context in which CS extinction treatment occurred. Possibly, (a) extinction of CS Y in Context D made Context D a negative occasion setter for CS X, and (b) extinction of CS X in Context B clearly did not make Context B a negative occasion setter for CS X. However, extensive prior research on the specificity of negative [and positive] occasion setting has found that occasion setters are most specific for the CS used in creating the occasion setter in question, next most specific for CSs used creating other occasion setters, and have least influence on responding to a CS that has never been occasion set (e.g., Holland, 1989). This is diametrically opposed to the difference in suppression seen to CS X between Contexts B and D. Nor can the extensive exposures that were given to Contexts B and D (as well as C) explain the difference in suppression to CS X between Contexts B and D because the two contexts received the same amount of exposure, and additionally it is well documented that exposure to an occasion setter alone does little to alter its occasion setting properties (Holland, 1983). Thus, an account in terms of differential occasion setting by Contexts B and D seems highly implausible.

We want to draw attention to the fact that on the Test day, CS X was presented immediately upon subjects' being placed in the test context. This was done to maximize associative summation between the CS and the test context (see Miller, Grahame, & Hallam, 1990, for evidence that this procedure favors associative summation). Seemingly, the procedure worked in the present research. But it leaves open the possibility that our conclusion concerning the extinction context becoming a stimulus-specific inhibitor applies only given this procedure. The experiment reported here does not address this possible limitation.

A caveat of the present research is that no retardation test was conducted to demonstrate that the extinction treatment made the extinction context a conditioned inhibitor that can pass a retardation test as well as a summation test for conditioned inhibition. This omission was predicated on the grounds that it was the potential of a conditioned inhibitor to produce a [negative] summation effect that we think sometimes contributes to renewal, not its potential to pass a retardation test. More empirically, Polack et al. (2012) demonstrated that a very similar extinction treatment resulted in a context that passed both a retardation test and a summation test.

As a final point, we recommend against restricting the definition of renewal to recovery that only is observed in the absence of evidence that the test contexts have acquired excitatory or inhibitory associative value (e.g., Nelson et al., 2011). Rather, we encourage the search and empirical evaluation of potential sources of the renewal effect, not confounding the behavioral phenomenon with its potential underlying mechanisms.

#### Author statement

All three authors participated in the design of the experiment. ML collected and analyzed the data. CP and RM checked the data analysis. ML drafted the initial manuscript. CP and RM critiqued the initial manuscript. RM did the final revision.

#### Acknowledgements

National Institute of Mental Health Grant 33881 supported this research. Mario Laborda was partially supported by Program U-Apoya, University of Chile. The data and statistical analyses reported in this paper are available from either ML or RM. The authors would like to thank Cara Burney, Henry Cham, Lisa Mash, and Gonzalo Miguez for their comments on an earlier version of this

manuscript. Inquiries concerning this research should be addressed to Ralph R. Miller, Department of Psychology, SUNY–Binghamton, Binghamton, NY 13902-6000, USA.

## Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:<https://doi.org/10.1016/j.lmot.2020.101623>.

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