SHORT TITLE: EXTINCTION-CUES AND OPERANT PERFORMANCE

The Reoccurrence of Voluntary Behavior in Humans is Reduced by Retrieval Cues from Extinction

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Abstract

Changes in the temporal as well as the physical context produces the reappearance of extinguished behaviors. Furthermore, combining both kinds of contextual stimuli often causes greater levels of recovery. The current experiment explored the impact of extinction reminders on spontaneous recovery, renewal, and a combination of both effects using an instrumental learning task with humans. All participants learned to shoot at enemies in a videogame. Then, throughout extinction, the instrumental response was eliminated. We found a return of the extinguished behavior by introducing a retention interval of 48 hours, by changing the physical background and by testing participants in a spatiotemporal context different from the extinction context. However, we also found that the presentation of a stimulus directly associated with extinction attenuates all three forms of operant reoccurrence. These results are consistent with the perspective that emphasizes that context plays a key role in response-recovery phenomena. Moreover, our findings may be promissory for therapeutic strategies involving relapse treatment.

Key words: Extinction-Cue, Human Participants, Instrumental Behavior, Spontaneous Recovery, Renewal.

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The loss of operant responding produced by withholding the reinforcer (extinction) is not permanent (e. g., Rescorla, 2001). There are several reports that show that extinguished responses can return, either by executing the test outside of the extinction context (renewal; e. g., Nakajima, Tanaka, Urushihara & Imada, 2000; Vila, Romero & Rosas, 2002) or by testing the subjects after a temporal delay (spontaneous recovery; e. g., Graham & Gagné, 1940; Romero, Vila & Rosas, 2003).

Given the behavioral parallelisms between post-extinction response restoration and the reappearance of unwanted behaviors that had previously been eliminated through therapy (e. g., self-injury), effects like spontaneous recovery and renewal have been proposed as laboratory models for the study of relapse (see Kelley, Liddon Ribeiro, Greif & Podlesnik, 2015 and Lerman, Kelley, Van Camp & Roane, 1999 for examples of renewal and spontaneous recovery with clinically relevant populations). Furthermore, some researchers have pointed out that understanding the mechanism underlying these laboratory models plays an important role in the development of behavioral techniques with long-term effectiveness for preventing the relapse of problem behavior (e. g., Bouton, Winterbauer & Todd; 2012; Wathen & Podlesnik, 2018).

Although different accounts for spontaneous recovery and renewal have been provided (see McConnell & Miller, 2014 for a review), Bouton and colleagues have proposed one of the most common approaches to understand both laboratory models of operant relapse (e. g., Bouton, 2018; Bouton et al., 2012). In short, said perspective assumes that the response decrement during extinction in fact reflects an inhibitory learning to not perform the response trained originally (e. g., Todd, 2013; see also Rescorla, 1993). However, this response inhibition is difficult to sustain outside of the context in which it was learned (a context-dependent form of inhibition; see Bouton, 2014; Trask, Thrailkill & Bouton, 2017). Thereby, a contextual change (e. g., temporal or physical; Bouton, 2010) between the extinction context (e. g., therapeutic setting) and the test context (e. g., post-treatment setting) would promote the restoration (relapse) of the behavior learned before extinction (e. g., unhealthy actions such as overeating).

In line with that reasoning is the idea that, in order to prevent the return of the operant behavior, participants should be provided with signals that evoke the inhibitory learning acquired in the extinction context (e. g., no responding; see Bouton & Todd, 2014). One way to achieve that is by testing participants in the presence of a brief stimulus directly associated with extinction (i. e., extinction-cue; Brooks & Bouton, 1993). In recent years, there have been studies that are consistent with that prediction; showing that the use of an extinction-cue (an auditory cue) mitigates the spontaneous recovery (Bernal-Gamboa, Gámez & Nieto, 2017) and the renewal (e. g., Willcocks & McNally, 2014; see also Nieto, Uengoer & Bernal-Gamboa, 2017) of operant performance.

Despite the fact that the above-mentioned findings strongly suggest that the extinction-cue strategy could be promising for clinicians interested in reducing the likelihood of problem behavior relapse, two important issues about the possible boundaries of those results should be noted: 1) the extinction-cues' effectiveness for reducing the reappearance of previously extinguished operant responses has only be reported in studies with rats; and 2) the impact of the extinction-cues has only been tested either on spontaneous recovery or on renewal, but not in combination. Thus, the present experiment was designed to explore whether the data reported with rats could be extended to humans by using a computer task that involves instrumental responses. Moreover, given that it has been suggested that, under clinical conditions, response restoration might involve a combination of different sources of relapse (e. g., Podlesnik, Kelley, Jimenez-Gomez & Bouton, 2017; Wathen & Podlesnik, 2018), the current experiment also evaluated the impact of an extinction-cue under conditions that change both spatiotemporal contextual cues (i. e., spontaneous recovery and renewal).

The experimental design is shown in Table 1. All experiments involved a within-subjects design. We used a videogame task based on previous studies (e. g., Gámez & Rosas, 2005, 2007; see also, Gámez & Bernal-Gamboa, 2018) in which participants were requested to defend two Andalusian beaches (Context A or Context B, counterbalanced) against invasion by shooting missiles at tanks or planes, which was done by clicking on their respective pictures (i. e. half of the subjects in each group performed R1 in Context A; while the other half emitted R2 in Context B). The enemies' explosion (tanks, O1, or planes, O2) served to reinforce the shooting behavior (i. e., instrumental response). Then, both responses (shooting at tanks or at planes) underwent extinction (the shooting did not produce the destruction of any enemies) in the same contexts in which acquisition took place. Throughout extinction, a red-colored rectangle appeared on top of the screen (i. e., extinction cue) for both enemies. Finally, both responses were tested.

For Experiment 1a and 1c, testing was conducted 48 hours after the last extinction trial, while participants in Experiment 1b received the test immediately after the extinction phase. In addition, for participants in Experiment 1b and 1c, both responses were tested in the opposite contexts of the previous phases (i. e., R1 in Context B and R2 in Context A) whilst Experiment 1a participants' responses were tested in the same contexts as in acquisition and extinction (i. e., R1 in Context A and R2 in Context B). Note that only the target response (R1) was tested in the presence of the extinction-cue. Thus, according to the aforementioned approach (e. g., Bouton, 2018), the presentation of the extinction-cue should produce lower levels of operant responses in R1.

Method

Participants

Seventy-two (24 in each experiment) undergraduate students from the National University of Mexico (Mexico) participated in this study in exchange for course credit (59 women; M_{age} = 20.5 years; age range=19-24 years). They had no previous experience with this task. All students participated voluntarily and gave their informed consent before beginning the experiment, being free to abandon the task at any point of the process, although none of them did.

Apparatus and stimuli

Participants were trained individually, in eight adjacent PCs separated by fixed partitions. The procedure was implemented using the program SuperLab Pro (Cedrus Corporation) software. The task was similar to the one implemented by León, Abad, and Rosas (2010; see also, Gámez & Bernal-Gamboa, 2018). Participants played a computer game in which they had to defend Andalusia from air and land attacks. The main screen represented a viewer, simulating a participant's view from a hypothetical bunker in which they were supposed to be. Contexts were presented within the viewer's viewing area. Scenes of different beaches in Andalusia, Puerto Banús (urban beach) and Tarifa (natural beach) were counterbalanced as contexts A and B. The two attackers were a plane and a tank. The plane was presented in the sky, at the top right area of the context, while the tank was presented on the sand, at the bottom left area of the context. Both attackers could appear in one of two different positions within their respective areas on the context, so that it would give the impression of movement to the participant. The instrumental response consisted of clicking on either the plane or the tank (R1 and R2, counterbalanced). The destruction of the tank and the plane was counterbalanced as outcomes O1 and O2 across participants.

Procedure

The present experimental protocol was conducted under strict agreement of the guidelines established by the Ethical Committee of the Faculty of Psychology of the National University of Mexico. The instructions and all of the necessary information were presented in the participants' native language (Spanish) on the computer screen. Participants interacted with the computer using the mouse (left button). Instructions were presented in three screens using a black Times New Roman 26 bold font against a light-yellow background, to emulate the appearance of an old document. To advance through the instructions screens, participants had to click on a button labeled "next", placed on the bottom right corner of the screen. Each participant was initially asked to read the following instructions:

> "(Screen 1) Andalusia is under attack. Different parts of Andalusia are being assaulted by land and air. You are placed in the only bunker able to face the attackers. Use the mouse to launch missiles at the targets. Your goal is to destroy the attackers before they take over Andalusia. (Screen 2) The monitor represents the bunker's viewer, in which the different attackers you should face will appear.
> To shoot, click the left mouse button while the pointer is on the target. Your technology and weapons are older than theirs, so you will need to shoot several times to destroy them. (Screen 3) The battle begins! You have to destroy tanks and

planes before they take over the Andalusian coast. We are in your hands! GOOD LUCK!”

In each trial, either the tank or the plane were presented. Giving the appropriate response (i.e., clicking on the plane) was reinforced with the destruction of the attacker (outcome) on a variable interval (VI) 2-s schedule in which the availability of reinforcement varied randomly between 1 s and 3 s. Thus, in each trial, the participant had to click multiple times on the enemy in order to destroy it. The trial ended only after the participant gave the correct response and, hence, the enemy was destroyed (O1 or O2). The experiment was conducted in three phases (see the experimental design in Table 1).

Acquisition A screen displaying the message “Your detachment has been posted to… (name of the beach where the battle continued)” was presented for 2 s before starting training in each context. Participants received 10 training trials with each attacker. R1-O1 trials were conducted in two blocks of 5 trials in Context A, while R2-O2 trials were conducted in two blocks of 5 trials in Context B. Trial order within each context was random. Context order for half of the participants was ABAB and BABA for the other half.

Extinction. After the acquisition phase, all participants received 30 extinction trials with a duration of 4 s, identical to the acquisition trials except that responses were never reinforced. R1 underwent extinction in Context A and R2 in Context B. In each of those trials, we presented a red-colored rectangle in the upper portion of the screen (extinction-cue).

Test. For all participants, this phase started with the sentence: “Your detachment has been posted to…(name of the beach where the battle continued)”, which was presented for 2 s. After that, all participants received an extinction test trial in each context. Each trial lasted 4 s and the order in which the contexts were presented was counterbalanced across participants. For participants in Experiment 1b, this phase started immediately after the last extinction trial, while for Experiment 1a and 1c, the test was conducted 48 hours after the extinction phase. Note that, in this phase, only participants in Experiment 1b and 1c experienced a context change between responses (i. e., R1 was tested in Context B; R2 was tested in Context A), whereas contexts for Experiment 1a remained the same as in the previous phases (i. e., R1 was tested in Context A; R2 was tested in Context B). The red-colored rectangle (extinction-cue) was presented only during the R1 testing trial. The extinction-cue was not presented during R2 testingthe test of R2. The testing order was fully counterbalanced.

Dependent Variable and Statistical Analysis

The total number of mouse clicks on each enemy were recorded and translated as responses per minute. Responding was evaluated by analysis of variance (ANOVA). The rejection criterion was set at $p < 0.05$, and effect sizes were reported using partial eta-squared (η_p^2). Additionally, 90% confidence intervals for the effect sizes were calculated and reported for each analysis.

Results and discussion

Experiment 1a

Figure 1 shows the mean response per minute for both responses during 2-trial acquisition blocks (left panel) and during 3-trial extinction blocks (right panel). A 2 (Response) x 5 (Block) ANOVA conducted with the acquisition data confirmed that both responses were acquired similarly by all participants and that response rates increased as acquisition progressed, only finding a significant main effect of Block, $F(4, 92) = 30.53$, *p*

< .001, η_p^2= .86 [CI: .34-.61]. The main effect of the Response and Response x Block interaction did not reach significance, *F*<.81, p>.37, η_p^2< .03, showing there was no difference in acquisition between R1 and R2.

A 2 (Response) x 10 (Block) ANOVA conducted on the extinction data only found a significant main effect of Block, *F*(9, 207)= 6.92, *p* = .001, η_p^2= .81 [CI: .61-.73]. However, the main effect of Response and the interaction did not reach significance, *F*<0.80, p>.62, η_p^2< .32, indicating that extinction proceeds similarly for both responses.

In summary, although the response rate was quite high in the beginning of the training, particularly due to the simplicity of the task, we found a significant increase for both responses at the end of the acquisition phase. Moreover, the lack of reinforcement during extinction led participants to reduce their response rate in the presence of both contexts.

The effect of the passage of time on previously extinguished responses was then assessed. Figure 2 shows the mean responses per minute for R1 and R2 during the last extinction trial, as well as the test trial. If spontaneous recovery occurred, then we should find a higher response rate in Test than we do in Extinction. Furthermore, if the presentation of the extinction-cue in context A during the Test phase was effective enough to reduce the spontaneous recovery effect, then we should find a lower response rate for the response associated to that context (R1), when compared to the other one (R2). A 2 (Response, R1 vs. R2) x 2 (Testing, Last extinction trial vs. Test trial) ANOVA found a significant main effect of Response, *F* (1, 23) = 8.18, p= .009, η_p^2 = .26 [CI: .17- .67] and Testing, *F* (1, 23) = 18.22, p< .001, η_p^2= .44 [CI: .28- .74]. Moreover, the Response x Testing interaction was significant as well, *F* (1, 23) = 4.64, p= .04, η_p^2 = .18 [CI: .28- .74].

Follow-up comparisons showed an increase in the response rate between the last extinction trial and the test trial for R1, F (1, 23) = 13.38, p= .001, η_p^2 = .37 [CI: .45- .82], and for R2, F (1, 23) = 14.36, p=.001, η_p^2 = .38 [CI: .00- .46], showing that both response rates were higher in the Test phase than they were in the Extinction phases, that is, the spontaneous recovery effect took place for both R1 and R2. Interestingly, the simple effect of Response was not significant in the Last extinction trial, $F<1$, indicating no differences between R1 and R2 at the end of the extinction phase, but the simple effect of Response was significant in the Test trial, F(1, 23) = 8.13, p= .009, η_p^2 = .26 [CI: .14- .57], showing the mean responses per minute for R1 (in the presence of which the extinction-cue was presented) were comparatively lower than for R2.

To the best of our knowledge, this is the first evidence that shows that the spontaneous recovery of operant responses in humans can be reduced by using an extinction phase reminder.

Experiment 1b

The left panel of Figure 3 depicts the mean response per minute for R1 and R2 throughout the 2-trial acquisition blocks, while the right panel shows the performance for both responses during the 3-trial extinction blocks. A 2 (Response) x 5 (Block) ANOVA conducted with the acquisition data found a significant effect of Block, F(4, 92) = 15.25, p < .001, η_p^2= .75 [CI: .07-.35], showing the response rate increased as acquisition progressed, and Response, F(1, 23) = 12.18, p = .002, η_p^2= .35 [CI: .07-.35], indicates that the acquisition of R1 and R2 did not occur similarly. The Response x Block interaction did not reach significance, F<1. As can be seen in Figure 3, the response rate for R1 was lower than for R2. Nevertheless, planned comparisons contrasting response rates through blocks of R1 and R2 found that the difference was significant in R1, $F(4, 92) = 9.18$, $p < .001$, $\eta_p^2 = .65$ [CI: .07-.35], and in R2 $F(4, 92) = 8.10$, $p < .001$, $\eta_p^2 = .62$ [CI: .07-.35], which shows that both responses were acquired uneventfully.

A 2 (Response) x 10 (Block) ANOVA conducted on the extinction data found a significant main effect of Block, $F(9, 207) = 16.53$, $p < .001$, $\eta_p^2 = .91$ [CI: .52-.67], and Response, $F(1, 23) = 8.91$, $p = .007$, $\eta_p^2 = .28$ [CI: .07-.35]. The Response x Session interaction not reach significance, $F(4, 207) = 1.43$, $p = .26$, $\eta_p^2 = .46$. Again, planned comparisons show that both responses were extinguished smoothly, $F(9, 207) = 10.16$, $p < .001$, $\eta_p^2 = .86$ [CI: .07-.35] for R1, and $F(9, 207) = 12.93$, $p < .001$, $\eta_p^2 = .89$ [CI: .07-.35] for R2.

As in experiment 1a, these results show a significant increase of both responses in the end of the acquisition phase in contexts A and B, and a decrease in those responses' rate at the end of the extinction phase, in the presence of both contexts.

Figure 4 shows mean responses per minute for R1 and R2 in the last extinction trial and in the test trial. A 2 (Response, R1 vs. R2) x 2 (Testing, Last extinction trial vs. Test trial) ANOVA conducted with those data yielded a significant main effect of Response, $F(1, 23) = 9.63$, $p = .005$, $\eta_p^2 = .29$ [CI: .05- .56] and Testing, $F(1, 23) = 43.03$, $p < .001$, $\eta_p^2 = .65$ [CI: .05- .56]. The Response x Testing interaction was significant as well, $F(1, 23) = 5.84$, $p = .024$, $\eta_p^2 = .21$ [CI: .24- .65]. If a context switch between the extinction and the test phase yields an AAB renewal effect in both responses, we should find higher response rates in Test than we do in Extinction for both R1 and R2. The simple effect of Testing was significant for R1, $F(1, 23) = 19.12$, $p < .001$, $\eta_p^2 = .45$ [CI: .05- .56], and for R2, $F(1, 23) =$

31.29, $p < .001$, $\eta_p^2 = .58$ [CI: .05- .56], showing the renewal effect took place for both responses. Moreover, if the presentation of the extinction-cue for R1 (in context B) during the test phase was effective enough to reduce the renewal effect, we should expect lower responses per minute for R1than for R2. The analyses conducted to explore said interaction confirmed this hypothesis. The simple effect of Response did not reach significance in the Last extinction trial, $F<1$, indicating the extinction phase ended in a similar way for both responses R1 and R2, while the simple effect of Response was significant in Test trial, $F(1, 23) = 10.98$, $p = .003$, $\eta_p^2 = .32$ [CI: .14- .57], showing the response rate for R1 (which received the extinction-cue presentations) was lower than for R2.

As far as we know, this is the first report in the field of human instrumental learning that shows the benefits of using extinction-cues to reduce AAB renewal.

Experiment 1c

Figure 5 shows the mean response per minute for both responses during 2-trial acquisition blocks (left panel) and during 3-trial extinction blocks (right panel). A 2 (Response) x 5 (Block) ANOVA conducted with the acquisition data found a significant main effect of Block, $F(4, 88) = 29.51$, $p < .001$, $\eta_p^2 = .86$ [CI: .20-.49], showing the response rate increased as acquisition progressed, and of Response, $F(1, 22) = 9.69$, $p = .005$, $\eta_p^2 = .31$ [CI: .20-.49]. The Response x Testing interaction was not significant, $F=1.88$, p=.15, $\eta_p^2 = .28$. Although both responses were not acquired similarly by all participants, analyses conducted to compare response rates through blocks of R1 and R2 found that the difference was significant for R1, $F(4, 88) = 41.15$, $p < .001$, $\eta_p^2 = .89$ [CI:

.07-.35], and for R2 $F(4, 88) = 11.64$, $p < .001$, $\eta_p^2 = .71$ [CI: .07-.35], showing that both responses increased as acquisition progressed.

A 2 (Response) x 10 (Block) ANOVA conducted on the extinction data found a significant main effect of Response, $F(1, 22) = 12.69$, $p = .002$, $\eta_p^2 = .36$ [CI: .07-.35], and of Block, $F(9, 198) = 10.61$, $p < .001$, $\eta_p^2 = .87$ [CI: .56-.70]. Moreover, the interaction reached significance, $F(9, 198) = 5.56$, $p = .002$, $\eta_p^2 = .78$ [CI: .56-.70]. Follow-up comparisons to explore this interaction found the simple effect of Block was significant in R1, $F(9, 198) = 13.32$, $p < .001$, $\eta_p^2 = .89$ [CI: .56-.70], and in R2, $F(9, 198) = 5.47$, $p = .002$, $\eta_p^2 = .78$ [CI: .56-.70], showing the response rate decreased as extinction progressed. In addition, although the simple effect of Response was significant in the first extinction block, $F(1, 22) = 7.73$, $p = .011$, $\eta_p^2 = .26$ [CI: .56-.70] , it did not reach significance in the last extinction block, $F(1, 22) = 2.36$, $p = .139$, $\eta_p^2 = .09$, indicating the response rates for R1 and for R2 were similar at the end of the extinction phase.

As in previous experiments, these results show a significant increase of both responses at the end of the acquisition phase in contexts A and B, and a decrease in those response rates by the end of the extinction phase, in the presence of both contexts.

Figure 6 depicts mean responses per minute for R1 and R2 during testing. An ANOVA conducted with data from the last extinction trial and the test trial found a significant main effect of Response (R1 vs. R2), $F(1, 22) = 33.80$, $p < .001$, $\eta_p^2 = .61$ [CI: .06- .57] and Testing (last extinction trial vs. test trial), $F(1, 22) = 69.40$, $p < .001$, $\eta_p^2 = .76$ [CI: .33- .76]. The Response x Testing interaction was significant as well, $F(1, 22) = 9.38$, $p = .006$, $\eta_p^2 = .30$ [CI: .00- .43]. Analyses conducted to explore the interaction found the simple effect of Testing was significant for both R1, $F(1, 22) = 45.76$, $p < .001$, $\eta_p^2 = .67$

[CI: .00- .43], and R2, $F(1, 22) = 57.42$, $p < .001$, $\eta_p^2 = .72$ [CI: .00- .43], indicating the response was higher in Test than it was in Extinction, for both responses. On the other hand, the simple effect of Response was significant for Test, $F(1, 22) = 35.59$, $p < .001$, $\eta_p^2 = .62$ [CI: .00- .43], but not for Extinction, $F(1, 22) = 2.62$, $p = .120$, $\eta_p^2 = .10$, showing that in the test phase the response rate was higher for R2 than for R1, although there were no differences between both responses at the end of the extinction phase.

The present data is, to the best of our knowledge, the first demonstration of spontaneous recovery reduction plus AAB renewal of instrumental behavior by presenting a stimulus associated with extinction.

Finally, given the similarities between the three experimental designs an analytic comparison across experiments might be relevant. Figure 7 shows the mean response per minute for R1 (left panel) and R2 (right panel) during the test in all experiments. A one-way ANOVA comparing response rates of R1 found additivity between context change and retention interval, $F(2, 68) = 4.80$, $p = .01$, $\eta_p^2 = .12$ [CI: .02- .23]. Moreover, a similar comparison of R2 found that, the recovery produced by a combined effect of both relapse procedures (black bars) is greater than the levels of reoccurrence produced by using spontaneous recovery (white bars) and AAB renewal (gray bars) separately, $F(2, 68) = 7.96$, $p < .0001$, $\eta_p^2 = .19$ [CI: .06- .31].

These results are consistent with previous studies examining combined effects of procedures contributing to relapse effects such as spontaneous recovery plus renewal (e. g., Rosas & Bouton, 1998; Vila et al., 2002), renewal plus resurgence (e. g., Podlesnik et al., 2019; Trask & Bouton, 2016; but see Sweeney & Shahan, 2015) and resurgence plus reinstatement (e. g., Liggett, Nastri, & Podlesnik, 2018; cf. Bouton & Trask, 2016), supporting the perspective that proposed that given that all forms or relapse are governed by the same principles (e. g., Bouton, 2018), the combination of procedures may enhance relapse (e. g., Rosas, Vila, Lugo & López, 2001). Nevertheless, our data from Experiment 1c indicates that even after combinations of procedures that exacerbate the reappearance of extinguished behavior, extinction-cues are able to suppress relapse.

General discussion

The impact of an extinction-cue on the return of voluntary behavior was evaluated in an instrumental task with humans. We demonstrated the reappearance of operant responses, produced by spontaneous recovery, AAB renewal and when both effects are combined. However, the most important finding of the current experiment was that presenting an extinction-cue during testing mitigated all three forms of operant reoccurrence.

In line with that, it is important to note that given that presenting the red-colored rectangle only reduced but not eliminated the response recovery, our experimental manipulation of not removing the extinction-cue for R1 could not be seen as an ABB group, otherwise we should have observed the lack of the relapse for R1 in all three experiments (because there is no response recovery when extinction and test are conducted in the same context). Therefore, we can suggest that presenting the red-colored rectangle is just a cue associated with extinction but not the entirely extinction context.

The spontaneous recovery found in Experiment 1a (i. e., responding to R2) extended previous findings (e. g., López-Romero, García-Barraza & Vila, 2010; Romero et al., 2003) to a situation that involves an extinction procedure in a within-subject design. In addition, the data for R1 in Experiment 1a is consistent with recent findings with rats, which indicate that an extinction-cue is able to reduce the spontaneous recovery of operant responses (Bernal-Gamboa et al., 2017).

Responding to R2 in Experiment 1b indicates an AAB renewal, which is consistent with reports using discrimination reversal in instrumental learning with humans (e. g., Romero et al., 2003; see also, Vila, Romero & Rosas, 2002). Moreover, the attenuation of renewal (i. e., performance of R1) produced by the presence of an extinction-cue is in agreement with previous research done with rats (Nieto et al., 2017; Willcocks & McNally, 2014).

The higher levels of operant reoccurrence (responding of R2 in Experiment 1c) observed after combining a context change and a retention interval (i. e., spontaneous recovery + AAB renewal) are consistent with the findings of Vila et al. (2002), which reported greater response recovery following spontaneous recovery and ABA renewal in an instrumental retroactive interference task with humans. The critical result lies on the performance of R1, as it shows that using a retrieval cue from the extinction phase is effective even when a greater acquisition performance recovery was expected, given the joint effect of physical and temporal context changes (see Gámez & Bernal-Gamboa, 2019 for a similar result in a predictive learning task).

Our findings support reports that found that presenting stimuli directly associated with extinction attenuates other forms of operant recurrence. For instance, it has been reported that using neutral extinction-cues (e. g., audiovisual stimuli) can reduce reinstatement (Bernal-Gamboa et al., 2017; see also, Gámez & Bernal-Gamboa, 2018) and resurgence (e. g., Trask, 2019; see also, Craig, Browning & Shahan, 2017), but not rapid reacquisition (Willcocks & McNally, 2014). In addition, researchers have documented that even biologically relevant cues (reinforcers) paired with extinction attenuate renewal (Trask

& Bouton, 2016) and resurgence (Bouton & Trask, 2016). Overall, the results are generally consistent with the theoretical view that proposes that a similar mechanism (context change) underlies all forms of response recovery (e g., Bouton, 2018), since the data indicates that the use of signals learned in the extinction context suppress response reappearance.

Although we found that the return of operant behavior was reduced by presenting a stimulus associated with extinction, the specific mechanism through which the extinction-cue works is beyond our present experimental design. Nevertheless, several experiments strongly suggest that the extinction-cue might directly suppress the operant response through an inhibitory S-R association (e. g., Bouton, 2018; Nieto et al., 2017; Trask, 2019; Trask et al., 2017). Notwithstanding, more research is needed in order to fully comprehend the extinction-cues' functioning.

Another aspect that future studies might considerer incorporate in the experimental designs involving fictional tasks (e. g., videogames) with humans may be a nonreinforced control response. Some authors have acknowledged (e. g., Liggett et al., 2018) that control responses may allow for assessing whether increases in target responding reflect specific relapse effects or may reflect an artifact (i. e, more general increases in variability). Nonetheless, we consider that is difficult to explain our present data on the test trials based on the general increases in variability, because we found distinct levels of performance on R1 and R2. In addition, if the increment in the target response on testing was due to variability, we should have observed similar levels of response in the R2 in all experiments, which was not the case

As previously pointed out, our present results may have clinical implications in the development of behavioral treatments to prevent relapse of unhealthy voluntary actions following therapeutic elimination (e. g., Podlesnik & Kelley, 2015). In particular, our findings indicate that clinicians might consider including neutral but salient stimuli during therapy sessions, which the client could use later (outside therapy) because treatment reminders (extinction-cue) may promote long-term maintenance (after changes in the temporal context) and generalization (following changes in the physical context) of psychotherapeutic treatment (see Fisher, Greer, Fuhrman, & Querim, 2015 for an example of something similar to an extinction-cue after Functional Communication Training). Furthermore, our data clearly indicates that such therapy reminders might be still effective even when an acute return of the problem behavior is expected (e. g., combination of relapse sources).

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Table 1

Experimental Designs

Experiment	Acquisition	Extinction	Retention Interval	Test
1a	10 A: R1-O1 10 B: R2-O2	15 A*: R1- 15 B*: R2-	48 hrs	1 A*: R1- 1 B: R2-
1b	10 A: R1-O1 10 B: R2-O2	15 A*: R1- 15 B*: R2-	0 hrs	1 B*: R1- 1 A: R2-
1c	10 A: R1-O1 10 B: R2-O2	15 A*: R1- 15 B*: R2-	48 hrs	1 B*: R1- 1 A: R2-

Note: Contexts A and B were the beaches of Puerto Banús and Tarifa, counterbalanced. “R1” and “R2” stands for clicking on the plane or on the tank, counterbalanced. “O1” and “O2” means plane or tank destruction, counterbalanced. “*” Stands for the extinction-cue. Numbers indicate the amount of trials conducted.

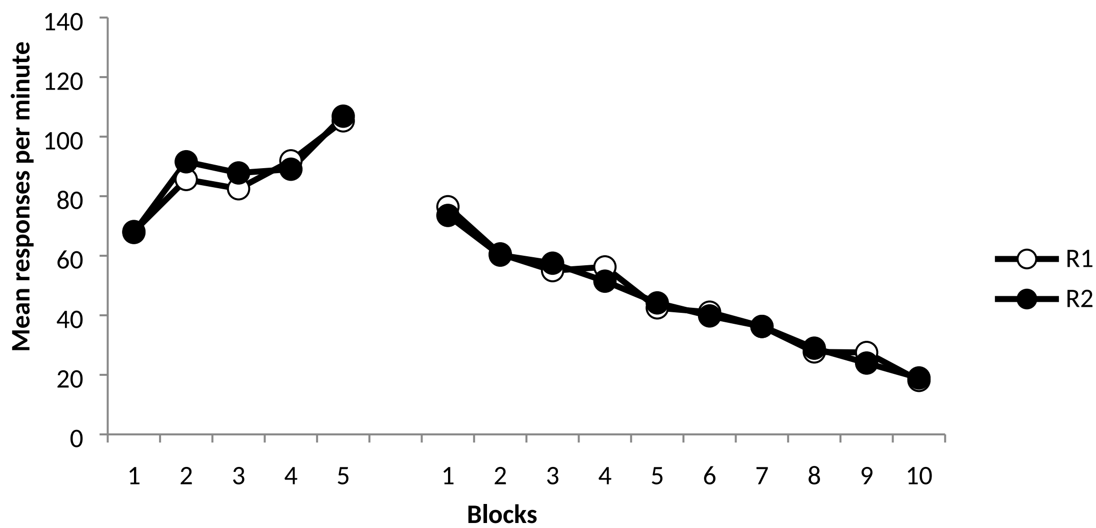

Figure 1. Mean responses per minute for R1 and R2 during acquisition and extinction in Experiment 1a.

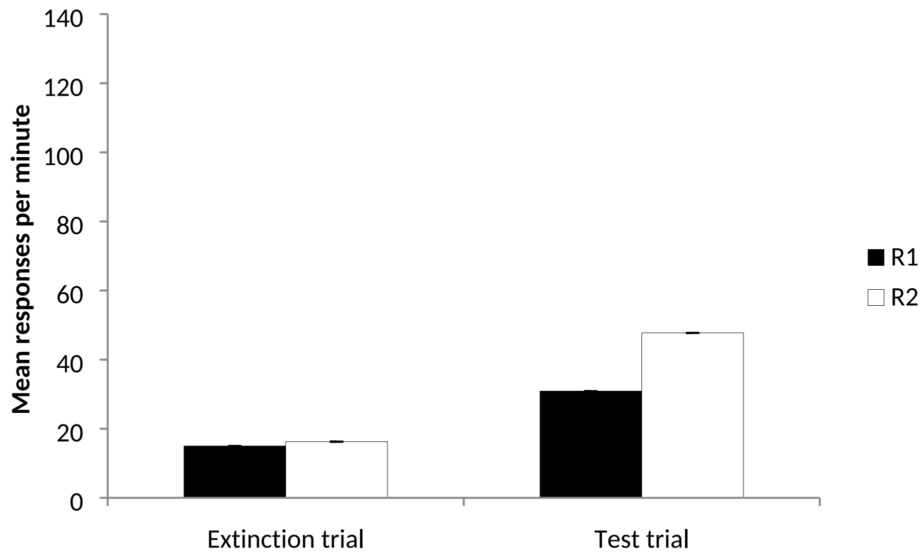

Figure 2. Mean responses per minute for R1 and R2 during the last extinction trial and the test trial in Experiment 1a.

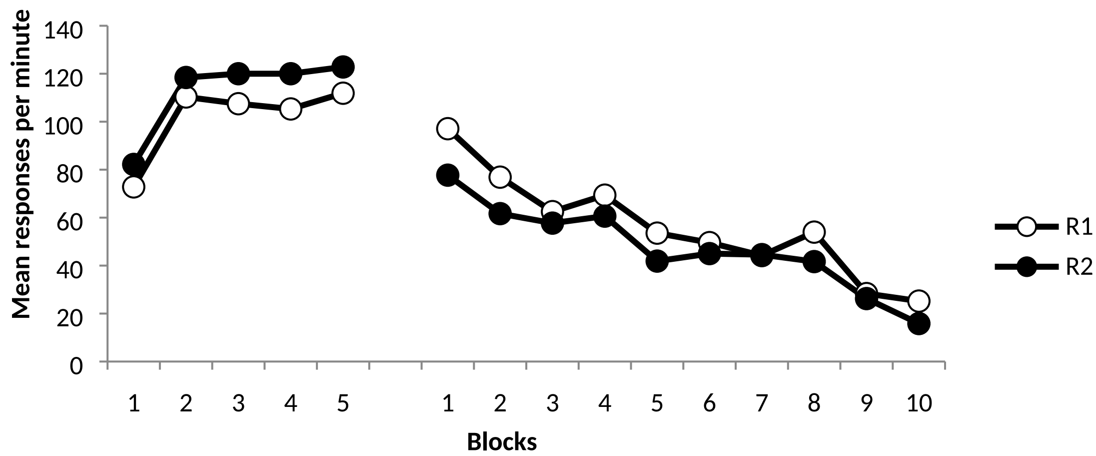

Figure 3. Mean responses per minute for R1 and R2 during acquisition and extinction in Experiment 1b

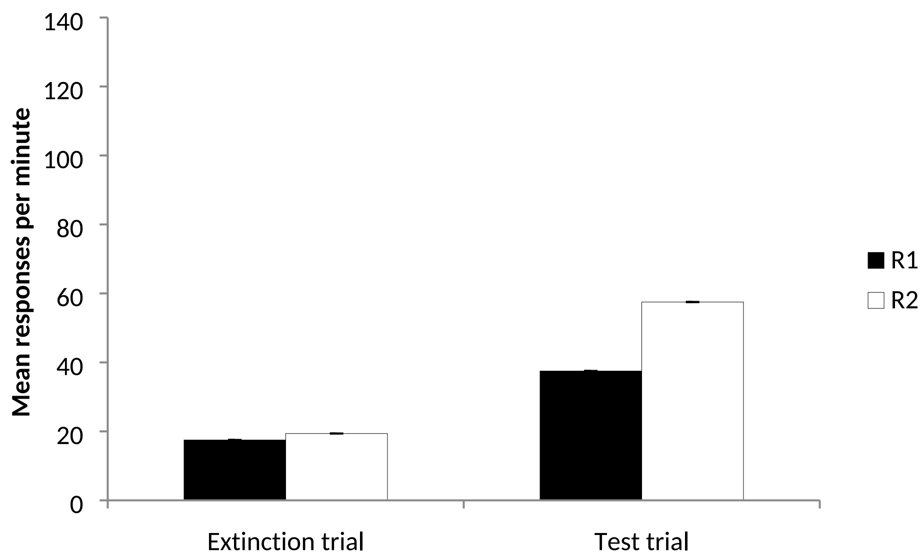

Figure 4. Mean responses per minute for R1 and R2 during the last extinction trial and the test trial in Experiment 1b.

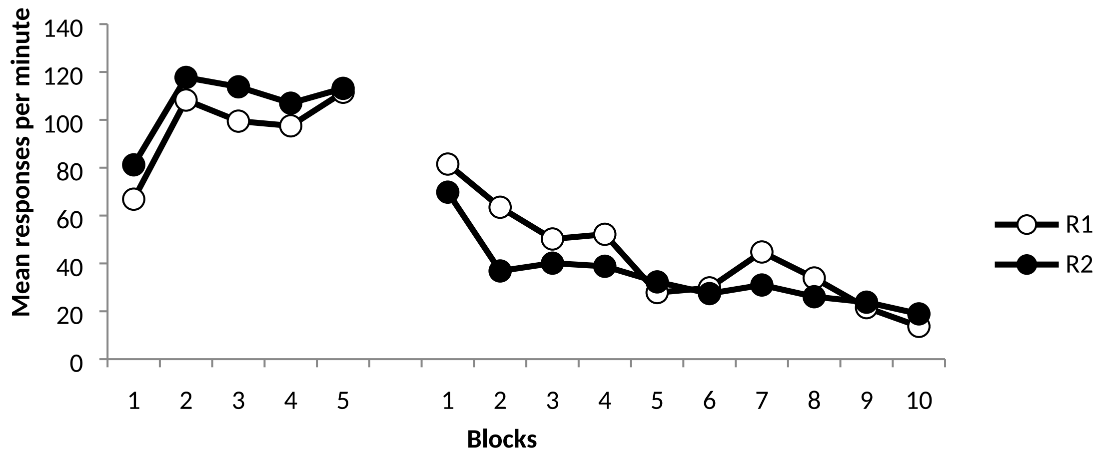

Figure 5. Mean responses per minute for R1 and R2 during acquisition and extinction in Experiment 1c.

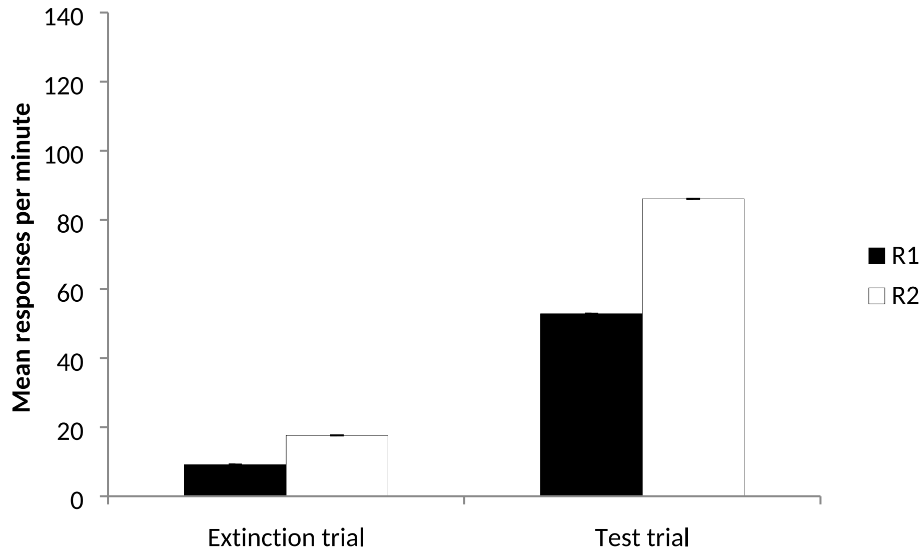

Figure 6. Mean responses per minute for R1 and R2 during the last extinction trial and during the test trial in Experiment 1c

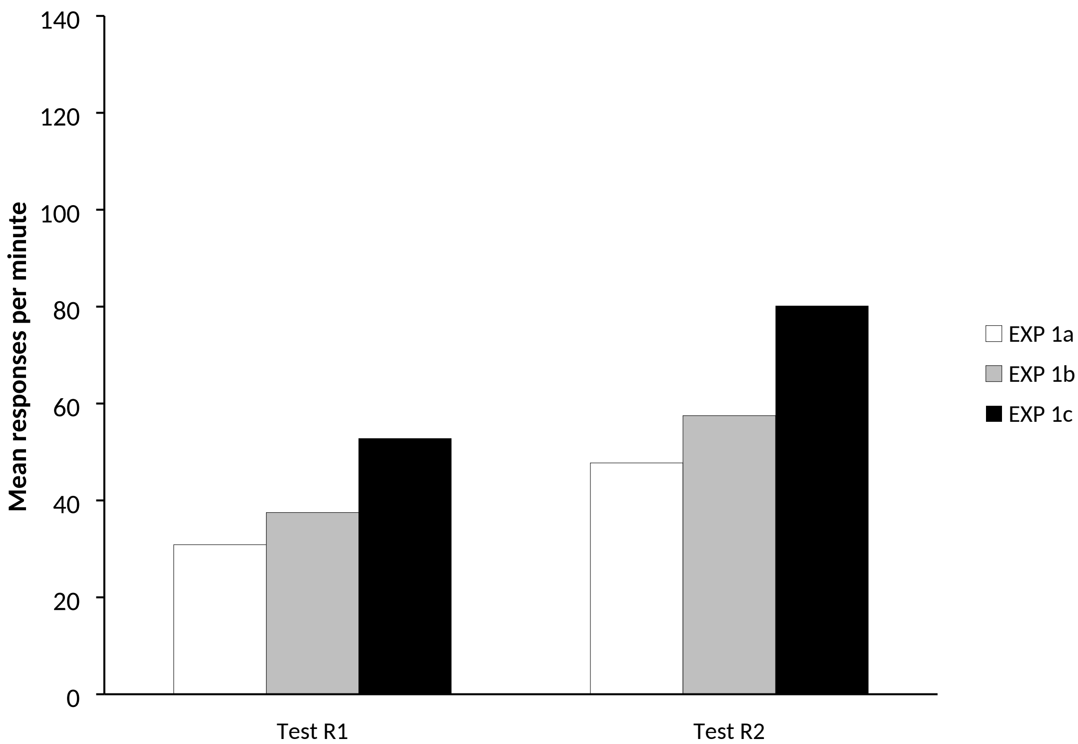

Figure 7. Mean responses per minute for R1 and R2 during the test trial in all experiments.