THE EFFECT OF MASSIVE EXTINCTION TRIALS ON THE RECOVERY OF HUMAN FEAR CONDITIONING

EL EFECTO DE LOS ENSAYOS MASIVOS DE EXTINCIÓN SOBRE LA RECUPERACIÓN DEL CONDICIONAMIENTO DEL MIEDO HUMANO

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Abstract: Given the mixed results in literature and the lack of human studies, a fear conditioning paradigm was used to evaluate whether the use of massive or moderate extinction trials have a differential effect on the recovery of extinguished fear, when assessed outside of the extinction context (an abc renewal design), and after a delay (spontaneous recovery). 32 college students were randomly assigned to massive (80 conditioned stimulus presentations) and moderate extinction (10 conditioned stimulus presentations) groups. Results showed that massive extinction produced a significantly lower spontaneous recovery than moderate extinction, but that effect decreased when tested outside of the extinction context (renewal). These results question the applicability of this technique in the therapeutic context.

Key words: pavlovian, exposure, anxiety, disorders, experimental psychology.

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Extinction has been used as a model for exposure therapy (e.g., Abramowitz, 2013; Craske, 2015), and is the treatment of choice for anxiety disorders (Chambless & Ollendick, 2001). Although conditioned stimuli (cs) alone presentations attenuate the conditioned response, an extinction procedure is well established as not destroying the original conditioned-unconditioned stimuli (us) association (Todd, Vurbic, & Bouton, 2014). Among the evidence demonstrating that such an association is not lost following extinction, it has been observed that extinguished responding is reestablished when testing takes place outside the extinction context (renewal; e.g., Vurbic & Bouton, 2014) and when a delay between extinction and testing is imposed (spontaneous recovery; e.g., Pavlov, 1927; Vurbic & Bouton, 2014). Accordingly, Bouton (1993, 2014) has suggested that experimental extinction involves the formation of an inhibitory-like association (cs-no us) whose expression depends on the spatiotemporal context in which extinction took place.

Of direct interest for the present report, the effects of a massive number of extinction trials have already been evaluated in non-human animals, although with mixed results (e.g., Denniston, Chang, & Miller, 2003; Laborda & Miller, 2013; Tamai & Nakajima, 2000). On one hand, using a conditioned suppression task with rats, Denniston et al. (2003) compared the effects of massive (800) and moderate (160) extinction trials in situations in which testing occurred in the context of acquisition or a new context (i.e., ABA and ABC renewal paradigms, in which acquisition occurs in context A, extinction in context B, and testing in context A or C). Their results suggested that the renewal of extinguished fear was attenuated when participants received massive extinction, in comparison with a group that received moderate extinction training. Using the same paradigm, Laborda and Miller (2013) reported similar results. Following acquisition in one context and extinction in a second, recovery elicited by a spatiotemporal context shift (i.e., testing in a third context after some time since extinction) was attenuated by massive extinction trials (810 trials). Additionally, this effect showed to be additional to the positive effects of carrying out extinction in multiple contexts (810 trials divided in three different contexts); the combination of the treatments was more effective than each treatment alone in decreasing fear recovery.

On the other hand, at least three studies have failed to show the attenuation of the renewal of extinguished conditioned responses after a massive extinction treatment. As noticed by Laborda, McConnell, and Miller (2011), the critical difference between the studies that have found a massive extinction reducing recovery and those which have failed to find such a benefit is the amount of extinction trials used. Tamai and Nakajima (2000), Rauhut, Thomas, and Ayres (2001), and Thomas, Vurbic, and Novak (2009) used 112, 100, and 144 extinction trials, respectively, while Denniston et al. (2003), and Laborda and Miller (2013) used at least 800 extinction trials, suggesting that smaller quantities of extinction may not be enough for attenuating the response recovery.

For humans, the amount of evidence is smaller. Within research conducted to evaluate the effectiveness of prolonged exposure therapy, Foa et al. (2005; see Powers, Halpern, Ferenschak, Gillihan, & Foa, 2010, for a review) has found less conditioned responding in patients with post-traumatic stress disorder after eight prolonged exposure sessions. Although massive extinction and prolonged exposure therapy are not identical treatments, Laborda et al. (2011) proposed that they may be comparable, as both techniques involve increased time of exposure to the cs.

Given the mixed results in the non-human animal literature and the lack of studies using human participants, the present study examined, using a human fear-conditioning paradigm, whether a massive and a moderate number of extinction trials have a differential effect on the recovery of extinguished fear after a delayed context shift (i.e., spontaneous recovery and renewal). Massive extinction treatment was expected to enhance extinction learning, preventing the recovery of the extinguished fear response.

**METHOD**

**Participants**

Forty-two college students (23 female) of 23.38 years old on average (range 18-35; \(sd = 4.60\)) participated in the study and received a photocopy voucher as a compensation for their participation. Participants were initially recruited via mass email, and afterwards were selected by their age and medical records. All participants read and signed an informed consent before beginning the experiment and were randomly assigned to one of the two extinction treatments, group Mod (\(n = 20\)) and group Mas (\(n = 22\)), for moderate and massive extinction, respectively (see Table 1). The local ethics committee previously approved all the procedures used in the implementation of the present study.
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Instruments

The Symptom Check List (scl-90-R; Derogatis, 1975; Chilean version by Gempp Fuenenalba & Avendaño Bravo, 2008) is a questionnaire for self-report of psychological distress experimented by a person. It assesses nine symptomatic dimensions: Somatization, Obsessive-Compulsive, Interpersonal Sensitivity, Depression, Anxiety, Hostility, Phobic Anxiety, Paranoid Ideation and Psychoticism. In addition, it shows three global indexes that describe the severity of symptoms: the Global Severity Index (gsr), the overall rate of Positive Symptoms (pst) and the Index of Symptoms Intensity (psdi). The scale consists of 90 items with five possible responses on a Likert scale, from 0 (none) to 4 (very much). The alpha coefficient of internal consistency ranges from .81 to .90 and the test-retest reliability from .78 to .90.

The State-Trait Anxiety Inventory (stai; Spielberger, Gorsuch, & Lushene, 1970; Chilean version by Vera-Villarroel, Celis-Atenas, Córdova-Rubio, Buela-Casal, & Spielberger, 2007) is an anxiety questionnaire. It assesses two components: State (immediate) and Trait (general) levels of anxiety. The inventory consists of two scales with 20 items each, with four possible answers in a Likert-type scale, from 0 (never) to 3 (almost always). The alpha coefficient of internal consistency ranges from .83 to .91 and the test-retest reliability from .78 to .90.

The medical form was a short check-list of relevant medical information: history of psychiatric disorders, cardiac or other important illness and medications.

Stimuli

Three different black geometric figures, a square (5 cm a side), an equilateral triangle (5 cm at the base) and a circle (6 cm of diameter), presented in a computer screen functioned as Cs (X, Y and Z, counterbalanced). A 200 ms mild-electric shock delivered to the left forearm served as the us and was administered with variable intensity between participants (range: 8-25 mA). The stimuli were presented over one of three different background colors in the computer screen, blue, red or green, which served as contexts. Green and red were counterbalanced as contexts.

The expectation of an incoming us was measured in real time during each stimulus presentation using a visual analog scale (vas) located below the stimulus, at the bottom of the screen. By clicking and dragging with a mouse, the indicator could be set anywhere in a horizontal line, for which the far left end meant that the shock was certainly not expected, and the far right end meant that the shock was certainly expected. From left to right, the position of the indicator along the horizontal line was recorded as a value in the 1-100 range, quantifying us expectation. Boddez and colleagues (2013) proposed that the us expectancy rating can be considered as a valid method for human fear conditioning studies, because it fulfills four validity criteria: face validity, diagnostic validity, construct validity and predictive validity. Thus, us expectation can be considered to be similar to the expectation of danger, an expectation common to fear and anxiety disorders (Boddez et al., 2013).

Table 1. Experimental Design

<table>
<thead>
<tr>
<th>Group</th>
<th>Acquisition</th>
<th>Extinction</th>
<th>Renewal and spontaneous recovery tests</th>
<th>Expected responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moderate</td>
<td>A (X+)</td>
<td>B (10 X–)</td>
<td>C (X–)</td>
<td>High</td>
</tr>
<tr>
<td>(n = 16)</td>
<td>A (Y+)</td>
<td>C (10 Y–)</td>
<td>B (X–)</td>
<td>Medium</td>
</tr>
<tr>
<td></td>
<td>A (Z–)</td>
<td></td>
<td>C (Y–)</td>
<td>Medium</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>B (Y–)</td>
<td>High</td>
</tr>
<tr>
<td>Massive</td>
<td>A (X+)</td>
<td>B (80 X–)</td>
<td>C (X–)</td>
<td>Medium</td>
</tr>
<tr>
<td>(n = 16)</td>
<td>A (Y+)</td>
<td>C (80 Y–)</td>
<td>B (X–)</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>A (Z–)</td>
<td></td>
<td>C (Y–)</td>
<td>Low</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>B (Y–)</td>
<td>Medium</td>
</tr>
</tbody>
</table>

Notes: A, B and C represent the different contexts. X, Y and Z are three different conditioned stimuli. + = unconditioned stimulus; – = no unconditioned stimulus. High, medium and low represent increasing levels of expected conditioned responses.
for extinction and testing, while blue served as the acquisition context for all participants.

**Apparatuses**

Electric shock delivery was controlled by a Digitimer DS7A Constant Current Stimulator (Hertfordshire, U.K.) via a pair of steel disk electrodes of 8 mm diameter with 30 mm spacing.

The whole experiment was run on a Hewlett-Packard desktop computer interfaced with an Arduino© Uno board for shock delivery, and programmed with E-prime software (Psychology Software Tools, http://www.pstnet.com/).

**Procedure**

*Pre-Training.* The experimenter guided participants to a waiting area, in which they answered three questionnaires, the scl-90-R, the STAI, and a medical form, and signed the informed consent. After that, they were guided to the experimental room, in which the experimenter placed the electric shock electrodes. The intensity of the electrical stimulation was determined by gradually increasing the level of the shock and asking the participants to stop at a level that was “uncomfortable, but not painful”. Finally, the participants were instructed about the use of the VAS.

*Acquisition.* Acquisition training was the same for all participants and took place in Context A. Stimuli X and Y were presented six times each followed immediately by the US, while Z was presented six times alone. Each stimulus was presented for 8 s. The inter-trial interval (ITI) varied between 16, 20 and 24 s with a mean of 20 s. The background color (context) was present during the ITI.

*Extinction.* During the extinction phase, participants in group Mod received 10 presentations of stimulus X without the US (X–), while participants in group Mas received 80 X– presentations, both in Context B. Additionally, participants in group Mod received 10 presentations of Y without the US (Y–), while participants in group Mas received 80 Y– presentations, both in Context C. The mean ITI was 5 s (range 4–6 s) for both groups.

Successful massive extinction studies with rats have found differential results using a 1:8 ratio between the extinction trials in the moderate and massive conditions (Denniston et al., 2003; Laborda & Miller, 2013), and further evidence has shown that 10 extinction trials are enough to support successful extinction in humans (Vansteenwegen et al., 2006). Furthermore, this design controls the associative histories of both contexts in order to use them as testing contexts (Rescorla, 2008; Todd, 2013).

*Renewal and Spontaneous Recovery Test.* Immediately after the extinction phase was finished, a 5 min pause was made and the participants were asked to complete an alphabet soup. During this pause, the computer screen background remained black. After the pause, the spontaneous recovery test began. In a single block of four trials, two presentations of X– in Context B and two presentations of Y– in Context C were given. Immediately after that, during the renewal test, two presentations of X– in Context C and two presentations of Y– in Context B were given. The trial ordering within each block was counterbalanced. The duration of the CSS and ITIs were identical to the extinction phase. The context changed, when needed, after half the ITI duration had elapsed.

**Inclusion Criteria**

Only the participants’ data that met all the following criteria were analyzed: (1) scores on the VAS for X and Y larger than or equal to 80 on the last acquisition trial, indicating clear expectancy of the US; (2) VAS scores for Z lower than or equal to 20 on the last acquisition trial, indicating clearly that no US was expected; and (3) individual stimuli VAS scores were lower than or equal to 20 on the last extinction trial, indicating successful extinction.

**Statistical Analysis**

SCL-90-R, STAI and US expectancy were all analyzed using univariate and repeated measures analyses of variance (ANOVA) and further examined with pair-wise comparisons when necessary, adjusting the alpha level with a Bonferroni correction. The Greenhouse-Geisser correction for degrees of freedom was applied in case of violation of the sphericity assumption, as indicated by the Mauchly test for sphericity. Effect sizes, and their confidence intervals, are reported as partial eta squared (η²). An alpha level of .05 was used for all statistical analyses.

**RESULTS**

Data from 10 participants were excluded in the analyses. The final sample included 32 participants, 18 females and
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14 males ($M = 23.63$ years; $SD = 4.61$), 16 in each group balanced by sex. By one-way ANOVA differences between STAI and SCL-90-R were compared for the groups. No significant differences were found for STAI Trait, $F(1, 30) = 2.50, p = .12$, STAI State, $F(1, 30) = 0.84, p = .36$, or SCL-90-R sub-scales, $F_s(1, 30) > 0.11, p_s > .05$. There were no significant differences by sexes in STAI Trait, $F(1, 30) = 0.72, p = .39$, STAI State, $F(1, 30) = 0.25, p = .74$, or SCL-90-R sub-scales, $F_s(1, 30) > 0.10, p_s > .05$.

Acquisition

Figure 1A shows the mean expectancy ratings during the acquisition phase for X, Y and Z across trials for both groups. A repeated measures ANOVA, with stimulus (X, Y, and Z), and trial (1-6) as within-participant factors, and extinction type (massive or moderate) as between-participants factor, was conducted. There were an effect of stimulus, $F(2, 30) = 433.76, p = .00, \eta^2 = .93$, 95% CI [.87, .95], an effect of trial, $F(5, 27) = 26.81, p = .00, \eta^2 = .47$, 95% CI [.19, .63], and a Stimulus x Trial interaction, $F(10, 22) = 35.44, p = .00, \eta^2 = .54$, 95% CI [.27, .68]. No extinction type main effect or interactions involving it were found, all $p_s > .05$. Pair-wise comparisons revealed that expectancy ratings for X and Y were reliably higher than expectancy ratings for Z, both $p_s < .05$, and did not differ from each other, $p = .07$. Overall, the results indicate that participants learned to differentiate between stimuli that were followed by an electric shock and that which was not. Moreover, towards the end of training, responding to X and Y was nearly identical, setting the stage for extinction training.

Extinction

Figure 1B shows the mean expectancy ratings during the extinction phase for both groups. Before any major analyses, a repeated measures ANOVA on the extinction data for Stimuli X and Y was performed. Such analysis yielded no significant difference between the cues during the extinction phase, $F(1, 28) = 1.25, p = .27, \eta^2 = .04$, 95% CI [.00, .22]. Given that result and that X and Y had similar acquisition and extinction associative histories, their data were pooled for the analyses to follow, effectively increasing the number of observations to 32 cases per group.

Figure 1. Means of the Unconditioned Stimulus (US) Expectancy, where 0 indicates security that the charge will not occur and 100 indicates that the charge will surely occur. (A) Means of the US expectancy produced by stimuli X, Y and Z during the acquisition phase for the massive extinction and moderate extinction groups during the six trials. (B) Means of the US expectancy during the extinction phase for both groups (i.e., X and Y for both groups, data from these was pooled and presented together). For the moderate extinction group responding to all extinction trials are shown, while for the massive extinction group responding to only the first five and the last five extinction trials are shown. (C) Mean US expectancy ratings evoked by the extinguished stimuli (i.e., X and Y for both groups, data from these was pooled and presented together) during the renewal and the spontaneous recovery tests for moderate and massive extinction groups. RT = renewal test; SRT = spontaneous recovery test. Bars represent the mean standard error.
Given that the groups had different number of trials, the 10 extinction trials from group Mod were compared to the first five and last five trials from group Mas. A repeated measures ANOVA with trial (1-10), extinction stage (first five trials vs. last five trials) as within-participants factors, and extinction type as between-participants factor was carried out. The results revealed a main effect of the extinction stage, $F(1, 62) = 109.64, p = .00, \eta^2 = .63, 95\%$ CI [0.50, 0.78], and trial, $F(4, 59) = 51.09, p = .00, \eta^2 = .45, 95\%$ CI [.26, .58], but no reliable difference between extinction types, $F(1, 62) = 0.07, p = .77, \eta^2 = .002, 95\%$ CI [0.00, 0.05]. An Extinction Stage $\times$ Trial interaction was found, $F(1, 62) = 46.08, p = .00, \eta^2 = .01, 95\%$ CI [0.00, 0.11].

In summary, these results showed a decrement in us expectancy ratings during the extinction phase. Notably, the few trials involved in the moderate extinction treatment were enough to produce asymptotic response. Most importantly, there were no reliable differences between groups at both the initial and final stages of extinction.

**Renewal and Spontaneous Recovery Tests**

Figure 1C shows the mean expectancy ratings for both groups during the renewal and spontaneous recovery tests. Similar to the extinction phase, data for X and Y were pooled, yielding 32 observations per group. Again, a repeated measures ANOVA indicated no significant differences between the stimuli during the testing phase, $F(1, 30) = 0.00, p = .78, \eta^2 = .00, 95\%$ CI [0.00, 0.09].

A repeated measures ANOVA with context (B [spontaneous recovery] and C [renewal + spontaneous recovery]) as a within-participant factor, and extinction type and testing order (1-4) as between-participants factors was performed. The results revealed that us expectancy ratings were reliably higher in Context C than in Context B, $F(1, 62) = 14.97, p = .00, \eta^2 = .33, 95\%$ CI [0.08, 0.53]. Additionally, expectancy ratings were reliably lower after massive extinction than after moderate extinction, $F(1, 62) = 44.46, p = .00, \eta^2 = .12, 95\%$ CI [0.00, 0.34]. Testing order did not reliably affect ratings, $F(3, 56) = 0.39, p = .39, \eta^2 = .01, 95\%$ CI [0.00, 0.17]. A Context $\times$ Extinction Type interaction was found, $F(1, 56) = 0.52, p = .50, \eta^2 = .01, 95\%$ CI [0.00, 0.18], and no other significant main effects or interactions were found, $ps > .05$.

Posterior comparisons indicated that us expectancy ratings in the spontaneous recovery tests were significantly higher for the group Mod than for the group Mas, $t(62) = 5.86, p = .03$, indicating that massive extinction training was more effective than moderate extinction training in reducing the spontaneous recovery of extinguished fear. In renewal + spontaneous recovery tests, the us expectancy ratings were numerically, but not reliably, higher for group Mod than for group Mas, $t(62) = 1.02, p = .32$.

**DISCUSSION**

In the present experiment whether a massive or a moderate number of extinction trials have differential effects on the recovery of extinguished fear after a spatiotemporal shift was evaluated. Participants in both extinction treatments learned to respond differentially between stimuli that predicted the presence or absence of an electric shock. Moreover, they extinguished such responding, reaching similar levels of responding after extinction. Finally, in the testing phase, when excitatory cues were presented in the delayed extinction context (spontaneous recovery) the us expectancy was significantly lower after massive extinction than after moderate extinction. However, when a spatial shift was added, the us expectancy was equally renewed for both treatments.

These results suggest that the massive extinction treatment can attenuate the recovery of previously extinguished us expectancy after a time shift only, but not after time and spatial shifts combined. Hence, although massive extinction may strengthen extinction learning, it was found that this benefit does not seem to generalize to different spatial contexts. Even though the same proportion of extinction trials between the moderate and massive conditions of successful studies have been used (Denniston et al., 2003; Laborda & Miller, 2013), the possibility that more than 80 trials might be needed for massive extinction learning to withstand a change in spatial context cannot be currently rejected. Future research ought to explore different sets of parameters, whether they are different amounts of extinction, or control for different exposure lengths to the extinction context.

Using a within-participant design with multiple contexts and cues (Rescorla, 2008), is certainly a contribution for studying renewal in humans as participants. Robust renewal was obtained while at the same time controlling the contexts’ associative history and novelty. Todd (2013) proposed that if renewal is observed under these conditions, it is unlikely that the extinction context is directly inhibiting the representation of the us, because when the context associative histories are equivalent, both the extinction context (B) and a novel (C) should be equally inhibitory.
Instead, renewal was observed in both contexts, suggesting that each extinction context may have been specifically inhibiting the response that was extinguished in it. Recently, Polack, Laborda, and Miller (2012) have shown that possibility to be true in certain conditions. They found that massed extinction trials resulted in the extinction context passing summation and retardation tests, concluding that extinction contexts can become inhibitory when the extinction trials are close enough to each other, a condition sometimes met in massive extinction treatments. Although in the present study there were no specific tests to explore this mechanism, the use of short ITIs in the procedure may have made the extinction learning largely context-dependent. Such dependency could have in turn produced levels of inhibition loss that are similar between conditions, regardless of the amount of extinction training.

Coupled with the fact that participants considered the expected US to be aversive, the fact that massive extinction was not better than moderate extinction in reducing response recovery after a context shift undermines its applicability in the therapeutic context. Perhaps the use of conjoint techniques is necessary to prevent renewal. The practitioner interested in increasing both the short- and long-term benefits of exposure therapy could easily complement a massive extinction treatment with other techniques that promote cue generalization and/or facilitate the expression of the extinction memory in other contexts, such as extinction in multiple contexts (Laborda & Miller, 2012), or the use of extinction retrieval cues (Brooks & Bouton, 1994). Take the treatment of fear of arachnophobia as an example. In addition to massively exposing the patient to the aversive stimulus (e.g., the image of a spider, the spider itself, etc.), it might also be useful to carry out exposure in the multiple contexts associated with that stimulus (bathrooms, living rooms, etc.; Balooch, Neumann, & Boschen, 2012). The use of conjoint techniques to reduce the return of the conditioned response has received empirical support in the laboratory setting, and might have important implications for the clinical application of behavioral techniques. For example, Laborda and Miller, and Thomas et al. (2009) obtained favorable results using massive extinction trials in multiple contexts with rats as subjects. Indeed, these and other findings open the way for developing more robust methods of extinction, and increase the effectiveness of exposure therapy.

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