

Novelty-facilitated Extinction: Providing a Novel Outcome in Place of an Expected Threat Diminishes Recovery of Defensive Responses

Supplemental Information

Supplementary Results for Experiment 2

Reinstatement

Procedure. An exploratory test of reinstatement was conducted immediately following the spontaneous recovery test on Day 2 in human subjects. Reinstatement was induced by three unsignaled shocks, followed 17 seconds later by 10 trials of the CS+ and 10 trials of the CS-. The shock intensity was set to the level reached the previous day, but was not re-calibrated so as to avoid reinstatement prior to the test of spontaneous recovery.

Analysis. SCRs were analyzed using ANOVA treating CS type as a within-subjects factor and Group as a between-subjects factor, considered significant at $p < .05$. A reinstatement index was calculated using the criteria described in the main text for spontaneous recovery. In brief, the mean SCRs to the CS+ during early reinstatement (trials 1-3) were divided by the largest SCR to the CS+ during acquisition on Day 1.

Results. Figure S1 shows the results from each experimental phase, including reinstatement. In the early phase of the reinstatement test, the main effect of CS was trending ($p = .10$), but there was no CS X Group interaction ($p = .21$). Based on *a priori* hypotheses, post-hoc *t*-tests were conducted to investigate SCR differences between the CS+ and CS- within each group during early reinstatement. The SCR difference score (CS+ minus CS-) was significant in the EXT group ($t_{22} = 2.46, p = .022$), but was not significant in the NFE group ($p = .816$); however, this difference was not significantly greater in the EXT group than the NFE group ($p = .21$). In the late reinstatement test, the SCR difference score remained significant in the EXT group ($t_{22} = 2.15, p = .04$), while SCRs remained undifferentiated in the NFE group ($p = .63$). There was no difference in the reinstatement index between groups ($p = .65$).

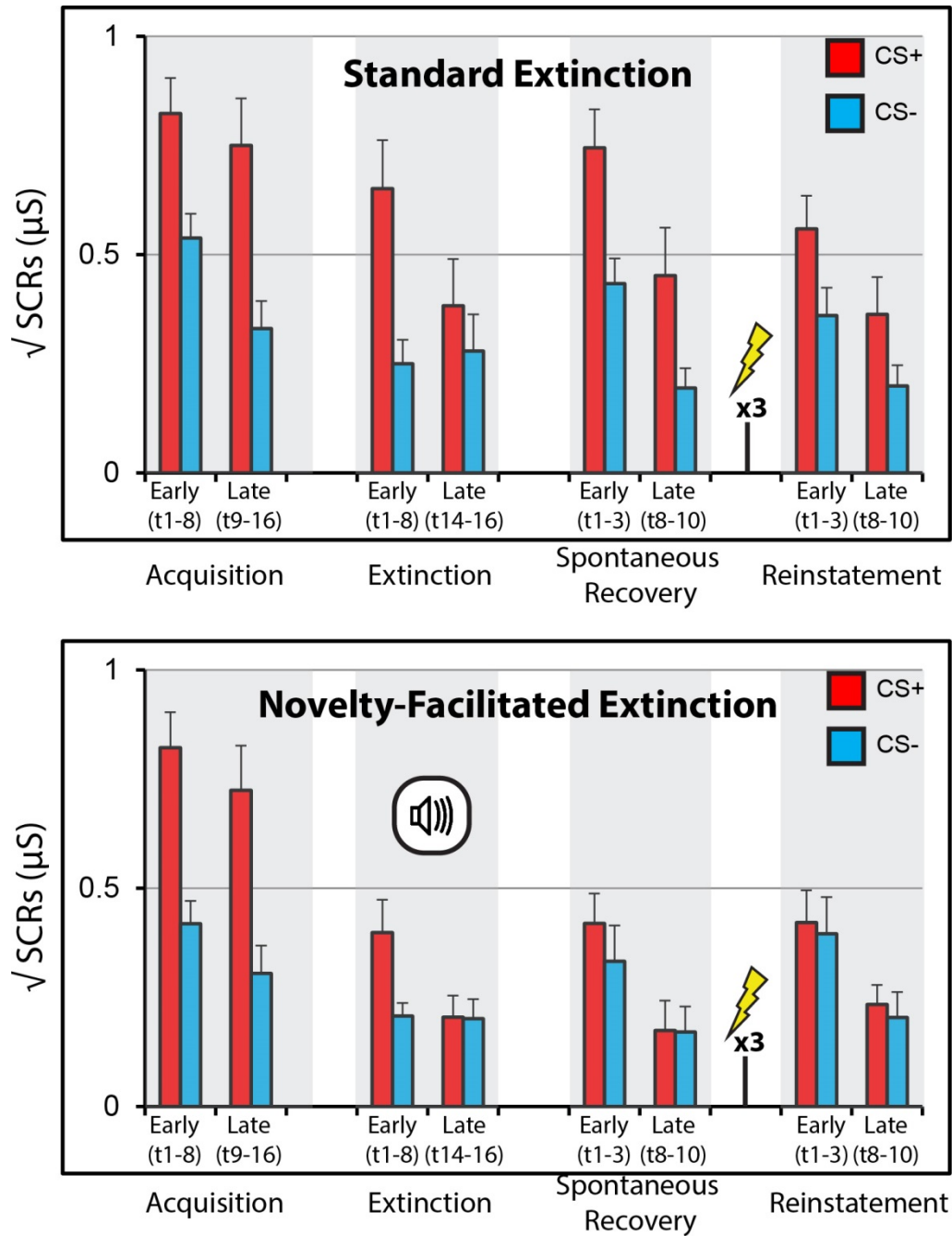


Figure S1. Mean SCRs across acquisition, extinction, spontaneous recovery, and reinstatement for the standard extinction and novelty-facilitated extinction groups. Error bars reflect standard error. The sound icon denotes the neutral tone outcome that replaced the electric shock during extinction. Subjects heard the tone over headphones (they did not see this sound icon). The lightning bolt denotes the shock US presented alone to reinstate the conditioned response. $\sqrt{\mu\text{S}}$ = square root transformed SCRs, in microsiemens. “t” = trials.

Correlations between Reinstatement and Intolerance of Uncertainty. There was a positive correlation between IUS and early reinstatement test in the EXT group ($r^2_{21} = .19, p = .036$) but not in the NFE group ($p = .77$). This association in the EXT group held when controlling for trait anxiety levels ($r^2_{20} = .21, p = .033$) (**Figure S2**).

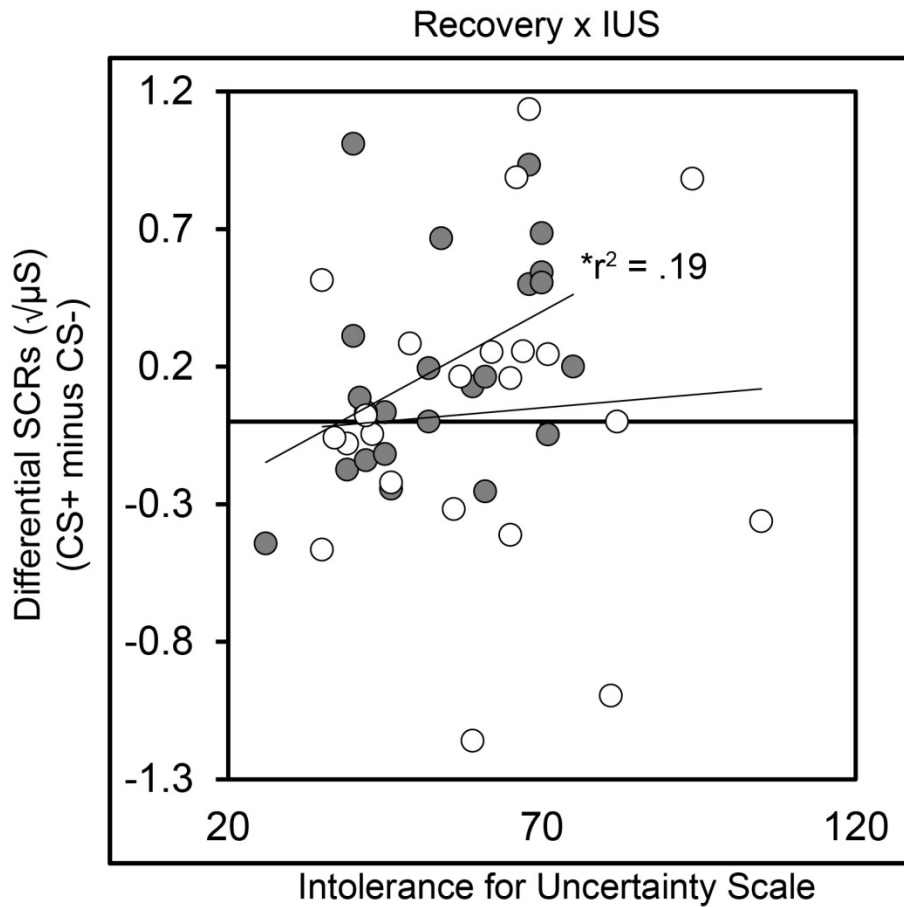


Figure S2. Early reinstatement SCRs correlated with self-reported intolerance for uncertainty (IUS) in the standard extinction group (gray circles), but not the novelty-facilitated extinction group (white circles).

Discussion. While results from the reinstatement test indicate an increase in differential SCRs in the EXT group, this difference was not significantly greater than in the NFE group. The reinstatement index also showed no differences between groups. Thus, the result of reinstatement is mixed as to whether NFE substantially reduces return of conditioned responses following unsigned presentations of the US.

We note some limitations to the reinstatement test. First, reinstatement tests were conducted following spontaneous recovery tests, and the EXT group maintained high levels of SCRs to CS+ by the end of spontaneous recovery while the NFE group showed reduced SCRs to both CS+ and CS- throughout the test (see **Results** in main text and **Figure S1**). These between-group differences at the end of the recovery test could obscure the results from the reinstatement test. Also, in order to prevent reinstatement prior to the test of spontaneous recovery, the shock was not re-calibrated on Day 2. Instead, we used the voltage reached the previous day. However, the intensity of the output voltage is determined by the current, and the current is determined by skin resistance, which can vary from day to day for the same individual. As a consequence, the subjective shock intensity level of the unexpected shock was not controlled for on Day 2. Subjects who found the unexpected shock to be particularly intense on Day 2 may have overgeneralized to the CS-, as shown in prior studies in rats where high intensity shocks lead to greater stimulus generalization (1). Correspondingly, other subjects may have found the shock intensity weaker on Day 2 than on Day 1, in which case the reinstatement shock could have been ineffective. These methodological details can complicate shock reinstatement procedures after a delay in human research that use tailored electric shock intensities. Notable, the extant research on reinstatement in humans is mixed and complex, as recently detailed by Haaker *et al.* (2), owing in part to the factors listed above.

Supplemental References

1. Baldi E, Lorenzini CA, Bucherelli C (2004): Footshock intensity and generalization in contextual and auditory-cued fear conditioning in the rat. *Neurobiology of learning and memory*. 81:162-166.
2. Haaker J, Golkar A, Hermans D, Lonsdorf TB (2014): A review on human reinstatement studies: an overview and methodological challenges. *Learning & memory (Cold Spring Harbor, NY)*. 21:424-440.