Brief Communication

Generalization of Extinguished Skin Conductance Responding in Human Fear Conditioning

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In a human fear conditioning paradigm using the skin conductance response (SCR), participants were assigned to two groups. Following identical acquisition, group ABA (n = 16) was extinguished to a generalization stimulus (GS), whereas group AAB (n = 20) was extinguished to the conditioned stimulus (CS). At test, presenting the CS in group ABA yielded a strongly recovered SCR. Presenting the GS in group AAB, on the other hand, did not disrupt the effects of extinction. We conclude that extinguishing the CS (group AAB) is an efficient strategy to overcome the stimulus specificity of extinction observed otherwise (group ABA). Clinical implications are discussed.

Learning mechanisms operating in conditioning experiments are known to be engaged in human anxiety disorders as well. More insight into the characteristics of these mechanisms is therefore crucial in enhancing the efficiency of therapeutic interventions. In particular, understanding the mechanisms that underlie the unlearning of patterns of behavior is indispensable. This is provided by experimental investigation into the extinction process of conditioned fear responses. In an extinction experiment, a stimulus that has been paired with an aversive event (e.g., an electric shock), hence eliciting fear response, is repeatedly presented in isolation (i.e., without the aversive event). The effect is typically a decay of the conditioned fear response.

One important aspect contributing to the efficiency of an intervention is its generalizability to new situations (see Rachman 1989, for a discussion on the clinical phenomenon of return of fear). For extinction, the ability of the produced response decrement to generalize to other stimuli can be experimentally tested. Vervliet et al. (2004) recently demonstrated that, in a human fear conditioning paradigm using skin conductance and shock expectancy as the dependent variables, the extinction effect is largely confined to the perceptual features of the extinction stimulus. The stimulus presented during extinction was perceptually somewhat different from the conditioned stimulus (i.e., was a generalization stimulus). In spite of substantial generalization of the conditioned responses to this new stimulus, final testing with the originally conditioned stimulus revealed that extinguishing the generalized response had no detectable effect. In the control group, the normal extinction effect was demonstrated using the conditioned stimulus throughout the entire experiment. This is the first experimentally controlled demonstration in human fear conditioning that extinction is stimulus specific. As argued by the authors, this may be clinically translated into situations where the extinction of fear to a phobic stimulus, obtained through therapeutic intervention (e.g., exposure therapy), a technique frequently used to reduce excessive fear by exposing the patient repeatedly to an exemplar of the fearful object, is lost upon confrontation with new instantiations of that stimulus.

This experiment was designed to test a possible strategy to overcome this lack of efficiency. Performing extinction with the originally conditioned stimulus may actually be a sufficient condition to ensure the generalization of its beneficial effects to new stimuli. Hence, after conditioning and extinguishing the same stimulus (A), the generalization stimulus (B) was presented at test (group AAB). If the generalizability of the extinction effect is as high as the generalizability of the conditioned fear response, no recovery of fear would be expected. A second group (ABA) was designed to replicate the stimulus-specificity effect observed in Vervliet et al. (2004), in that the generalization stimulus was presented during extinction but not during test. Importantly, a control stimulus was included in both groups that was never paired with the shock but underwent comparable stimulus changes. This differential conditioning procedure was used by Vervliet et al. (2004) to control for nonassociative effects such as orienting responses, habituation, dishabituation, and nonspecific enhanced uncertainty. The conditioning effect is defined as the statistical difference in conditioned responding to the two stimuli; extinction is said to be complete when this difference disappears. A difference between the groups at test would provide experimental support for the proposed strategy to enhance extinction efficiency in exposure therapy.

The experiment consisted of 24 trials. After a habituation phase (one presentation of the to-be-conditioned stimulus, CS+, and the control stimulus, CS−, without electric shock), four presentations of the CS+ were followed by the shock, whereas four presentations of the CS− were never followed by the shock (acquisition). The shock was an electrocutaneous stimulus, individually set at a level defined by the participant as “uncomfortable, but not painful.” During the subsequent extinction phase, four CS+ and four CS− trials were presented without shock in group AAB, whereas for group ABA the extinction phase consisted of four presentations of generalization stimuli (GS+ and GS−), always without shock. Finally, at test, the CS+ and the CS− were presented three times in group ABA. In group AAB, the GS+ and GS− was presented, also three times each. The rationale for the small number of acquisition trials was to prevent habituation to the shock before the end of the conditioning phase. The small number of extinction trials was aimed to reduce the total length of the experiment so that the participants would still show electrodermal responsivity at the time of the test phase (Lovibond et al. 2000). Conditioned fear responding was measured online by the SCR; the shock expectancy was retrospectively reported by the participants on completion of the experiment. A timeline of the experimental procedure, together with the set of stimuli, is presented in Figure 1.

SCRs were visually inspected and corrected for artifacts before they were analyzed statistically. SCR amplitudes are defined as the maximal increase starting within 1 to 4 sec after CS onset
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The crucial moment (ext2, test) × stimulus (experimental, control) interaction, although not presented in Table 1, was also significant in group ABA, $F_{(1,15)} = 8.93$, $Mse = 0.01$. Finally, the group (ABA, AAB) × moment (ext2, test) × stimulus (experimental, control) interaction is significant as well $F_{(1,14)} = 7.58$, $Mse = 0.02$. The size of the test discrimination in group ABA did not differ significantly from the discrimination on the second acquisition block $F_{(1,15)} = 2.36$, $Mse = 0.02$.

Concerning the retrospective shock-expectancy ratings, Figure 3 shows the averaged data for the different moments per group. The lower parts of the cells in Table 1 show the corresponding means and $F$-tests per block and per group. As suggested by the graph, conditioning was successful in both groups. On the first extinction moment, both groups still demonstrated

(i.e., the First Interval Response). Amplitudes were range corrected using the largest response elicited by the shock (peak between 9 and 15 sec after stimulus onset) as the maximum range for each individual. The corrected response magnitudes were averaged per block of trials, so that the experiment consisted of five blocks: 2 acquisition blocks, 2 extinction blocks, and 1 final test block. The means were subjected to a square root transformation to normalize the distribution prior to statistical analysis. Concerning the retrospective shock-expectancy data, the 5 rating moments per group were included in the analysis: 2 acquisition moments, 2 extinction moments, and 1 test moment. Within-groups analyses were performed within a separate 2 (stimulus: experimental, control) × 5 (block/moment: acq1, acq2, ext1, ext2, test) ANOVA per group. Between-groups differences were analyzed within the general 2 (group: ABA, AAB) × 2 (stimulus: experimental, control) × 5 (block/moment: acq1, acq2, ext1, ext2, test) ANOVA. The SCR results from the habituation phase were analyzed per group within a 2-way ANOVA (stimulus: CS+, CS−). Finally, the pleasantness and intensity ratings were analyzed separately in a 2-way ANOVA (group: ABA, AAB). The $\alpha$-level was set at .05 for all analyses. For every test, the appropriate degrees of freedom and error terms are reported.

In group ABA, 10 participants out of 16 reported observing 4 different geometrical shapes during the experiment (4 of the remaining participants actually reported noticing more than 4 shapes). In group AAB, the correct number of shapes was reported by 17 participants out of 20. The mean pleasantness rating for the shock was $-5.25$ in group ABA and $-5.70$ in group AAB. The mean intensity score for group ABA was proximal to the third label, namely intense ($M = 2.69$), as was the case in group AAB ($M = 2.60$). No statistically significant differences were observed between the two groups: pleasantness ratings, $F_{(1,34)} < 1$ and intensity ratings, $F_{(1,34)} < 1$.

Concerning the SCR, no difference between the CS+ and the CS− was observed during the preconditioning phase (habituation) ABA: $M_{CS+} = 0.51$, $M_{CS−} = 0.43$, $F_{(1,14)} = 1.97$, $Mse = 0.02$; AAB: $M_{CS+} = 0.47$, $M_{CS−} = 0.45$, $F_{(1,19)} < 1$. Figure 2 shows the SCR data averaged on block-level per group. The upper half of the cells in Table 1 show the means and the corresponding $F$-tests per block and per group. As suggested by the graph, conditioning was successful in both groups. On the first extinction block, which served as the generalization test in group ABA, the discrimination remained significant in both groups. As for acquisition, the between-groups difference was not significant on this moment. The conditioned SCR thus generalized substantially to the new stimulus pair in group ABA. Subsequent extinction was complete in group ABA, but not in group AAB, as indicated by the residual discrimination on the second extinction-block. Yet, the two groups did not differ significantly. Most importantly, the test discrimination was significant in group ABA, but not in AAB. The between-groups difference reaches the significance level as well. The crucial moment (ext2, test) × stimulus (experimental, control) interaction, although not presented in Table 1, was also significant in group ABA, $F_{(1,15)} = 7.58$, $Mse = 0.02$. The size of the test discrimination in group ABA did not differ significantly from the discrimination on the second acquisition block $F_{(1,15)} = 2.36$, $Mse = 0.02$.

Concerning the retrospective shock-expectancy ratings, Figure 3 shows the averaged data for the different moments per group. The lower parts of the cells in Table 1 show the corresponding means and $F$-tests per block and per group. As suggested by the graph, conditioning was successful in both groups. On the first extinction moment, both groups still demonstrated

![Figure 1](https://example.com/figure1.png)  
**Figure 1** Timeline of the actual experiment for groups ABA and AAB. The geometrical shapes are the stimuli presented to the participant. The lightning bolt symbolizes an administration of the electric shock. The minus sign and question mark refer to the absence of the electric shock. The number of presentations is indicated on the upper left side of each shape. The experimental stimulus is paired with the electric shock in the conditioning phase. The control stimulus is never paired with the electric shock. The triangle and parallelogram are counterbalanced within each group.

![Figure 2](https://example.com/figure2.png)  
**Figure 2** Mean First Interval Responses (i.e., range-corrected and square root-transformed SCR amplitudes between 1 s and 4 s after stimulus onset) for the two groups per stimulus type (experimental and control), as a function of blocks of trials. For group ABA, the two extinction blocks correspond to the generalization stimulus (CS+ vs. GS−), whereas for group AAB, the test block corresponds to the GS+ and the GS−. The second acquisition block (acq2) and the first and second extinction block (ext1 and ext2, respectively) each represent the mean of two consecutive trials. The test block (test) represents the mean of the three test trials. (Solid bars) CS+; (open bars) CS−.
the significant discrimination. Hence, the differential shock expectancy generalized well to the new stimulus pair in group ABA. Subsequent extinction was only partial, as both groups showed a residual and significant discrimination on the second extinction moment. Importantly, group ABA demonstrated a significant discrimination at test, contrary to group AAB. The between-groups difference on this moment was significant as well. The crucial moment (ext2, test) × stimulus (experimental, control) interaction, although not presented in Table 1, reached the significance level in group ABA \(F_{(1,15)} = 11.82, \text{Mse} = 5.93\). Finally, the group (ABA, AAB) × moment (ext2, test) × stimulus (CS+, CS-) interaction was also significant, \(F_{(1,34)} = 18.53, \text{Mse} = 4.30\). The size of the test discrimination in group ABA was significantly smaller than the discrimination on the second acquisition block, whereas group AAB showed an increase from extinction to test. In conclusion, the absence of a response recovery in group AAB was not attributable to such confounding variables.

Extinction of conditioned responses has sometimes been found to lack generalizability to new experimental situations. For example, response inhibition is known to be specific to the extinction context (contextual renewal). In ABA renewal, the fear conditioned stimulus is extinguished in a second context (B) before being tested in the conditioning context (A). In AAB renewal, the stimulus is conditioned and extinguished in the same context (A), followed by testing in a second context (B). In both cases, a recovery of the conditioned fear response has been observed (e.g., Bouton and Bolles 1979; Bouton and Ricker 1994; Thomas et al. 2003; for a demonstration of ABA-renewal in human fear conditioning, see Vansteenwegen et al. 2004). In comparison with our results, this points to a difference between the conditioned and extinguished stimulus appearance to be the crucial factor in generalizing response extinction.

Importantly, a number of nonassociative explanations for our results can be discarded on the basis of the empirical evidence. First, the observed response recovery in group ABA was not the result of orienting responses or dishabituation on confrontation with the test stimuli, as the responses to the control stimulus remain largely unchanged. Second, the substantial elicitation of the conditioned responses by the generalization stimulus on the outset of extinction ensures that generalization mechanisms were involved. The observed stimulus specificity of extinction at test in group ABA was therefore not attributable to a lack of perceptual similarity. Concerning group AAB, the absence of the response recovery at test did not result from a failure of discrimination: The postexperimental interview revealed that 17 participants out of 20 accurately noticed the four different experimental stimuli. The standard extinction procedure in this group could have caused a fatigue in skin conductance responsivity or a lowered attention towards the end of the experiment. However, the perseverance of (decremented) differential response to the CS+ versus the CS− until the last extinction block speaks strongly against this argument. Finally, dishabituation and/or orienting responses to the control stimulus at test can, in principle, mask recovered responding to the experimental stimulus. This is contradicted by the observation that neither stimulus showed an increase from extinction to test. In conclusion, the absence of a response recovery in group AAB was not attributable to such confounding variables.

### Table 1. Overview of Means and Statistical Significances

<table>
<thead>
<tr>
<th>Group</th>
<th>ACQ</th>
<th>EXT1</th>
<th>EXT2</th>
<th>TEST</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABA</td>
<td>(M_{CS} = .52, M_{C_{S-}} = .22)</td>
<td>(M_{CS} = .32, M_{C_{S-}} = .22)</td>
<td>(M_{CS} = .15, M_{C_{S-}} = .13)</td>
<td>(M_{CS} = .37, M_{C_{S-}} = .18)</td>
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<tr>
<td></td>
<td>(F_{(1,13)} = 18.79^{***})</td>
<td>(F_{(1,13)} = 7.08^{*})</td>
<td>(F_{(1,13)} &lt; 1)</td>
<td>(F_{(1,13)} = 12.21^{**})</td>
</tr>
<tr>
<td></td>
<td>(M_{SE} = .04)</td>
<td>(M_{SE} = .01)</td>
<td>(M_{SE} = 1.25)</td>
<td>(M_{SE} = .02)</td>
</tr>
<tr>
<td></td>
<td>(M_{CS} = .916, M_{C_{S-}} = 1.16)</td>
<td>(M_{CS} = 7.87, M_{C_{S-}} = 3.16)</td>
<td>(M_{CS} = 2.28, M_{C_{S-}} = .69)</td>
<td>(M_{CS} = 6.88, M_{C_{S-}} = 1.09)</td>
</tr>
<tr>
<td></td>
<td>(F_{(1,13)} = 174.55^{***})</td>
<td>(F_{(1,13)} = 28.37^{***})</td>
<td>(F_{(1,13)} = 6.80^{*})</td>
<td>(F_{(1,13)} = 45.20^{***})</td>
</tr>
<tr>
<td></td>
<td>(M_{SE} = 2.93)</td>
<td>(M_{SE} = 6.53)</td>
<td>(M_{SE} = 2.99)</td>
<td>(M_{SE} = 5.92)</td>
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<tr>
<td>AAB</td>
<td>(M_{CS} = .57, M_{C_{S-}} = .31)</td>
<td>(M_{CS} = .47, M_{C_{S-}} = .36)</td>
<td>(M_{CS} = .40, M_{C_{S-}} = .29)</td>
<td>(M_{CS} = .37, M_{C_{S-}} = .32)</td>
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<tr>
<td></td>
<td>(F_{(1,19)} = 29.40^{***})</td>
<td>(F_{(1,19)} = 8.55^{*})</td>
<td>(F_{(1,19)} = 6.19^{*})</td>
<td>(F_{(1,19)} = 1^{*})</td>
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<tr>
<td></td>
<td>(M_{SE} = .02)</td>
<td>(M_{SE} = .02)</td>
<td>(M_{SE} = .02)</td>
<td>(M_{SE} = .02)</td>
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<tr>
<td></td>
<td>(M_{CS} = 9.65, M_{C_{S-}} = 1.25)</td>
<td>(M_{CS} = 8.68, M_{C_{S-}} = 1.70)</td>
<td>(M_{CS} = 3.68, M_{C_{S-}} = 1.13)</td>
<td>(M_{CS} = 4.88, M_{C_{S-}} = 4.13)</td>
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<tr>
<td></td>
<td>(F_{(1,19)} = 303.66^{***})</td>
<td>(F_{(1,19)} = 83.19^{***})</td>
<td>(F_{(1,19)} = 31.30^{***})</td>
<td>(F_{(1,19)} = 2^{*})</td>
</tr>
<tr>
<td></td>
<td>(M_{SE} = 2.32)</td>
<td>(M_{SE} = 5.85)</td>
<td>(M_{SE} = 2.08)</td>
<td>(M_{SE} = .02)</td>
</tr>
</tbody>
</table>

\(*P < .05. **P < .01. ***P < .001. The upper half of each cell concerns the SCR, the lower half of each cell concerns the shock-expectancy. CS+ and GS+ refer respectively to the conditioned and generalization exemplar of the experimental stimulus. CS− and GS− refer respectively to the corresponding 'conditioned' and 'generalization' exemplar of the control stimulus. ACQ, EXT1, EXT2, and TEST refer to the second acquisition block, the first and second extinction block, and the test block, respectively. ABA and AAB are the experimental groups.\)
The participants in our experiment were 36 first-year economy students who participated to earn credits. They were all given informed consent and informed that they could decline to participate at any time. Sixteen participants were assigned to group ABA, twenty to group AAB. The stimuli and apparatus are described in detail elsewhere (Vervliet et al. 2004). Figure 1 provides a visual presentation of the main features. Stimuli were always presented for 8 sec. Intertrial intervals varied randomly between 15 and 25 sec with a means of 20 sec. The conditioning and extinction phases were each divided into two blocks of two experimental and two control stimulus presentations (randomized per block). The experimental and control stimulus were counterbalanced for half of the subjects in each group. The test block consists of three presentations. Additionally, the first extinction trial and the first test trial were both counterbalanced, so that half of the participants were first confronted with the experimental stimulus on these moments. The other half received a presentation of the control stimulus first. After the test phase, the participants were first asked for the number of geometrical shapes they were able to distinguish during the course of the experiment. Next, they were asked to retrospectively rate their shock expectancy on an 11-point scale (labeled from 0—certainly no shock to 10—certainly shock) for 5 different moments of the experiment: the beginning and ending of the conditioning phase, the beginning and ending of the extinction phase, and the beginning of the test phase. They were asked to do this first for the experimental stimulus and then for the control stimulus. Afterwards, the participants were asked to rate the pleasantness of the unconditioned stimulus on an 11-point graphic scale (anchored: −10, unpleasant and +10, pleasant) and unconditioned stimulus intensity on a 5-point categorical scale (weak, moderate, intense, enormous, and unbearable).

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