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Beyond extinction: Habituation eliminates conditioned skin conductance across contexts

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ABSTRACT

A marked signature of fear extinction is its vulnerability for relapse. Here, we departed from the standard extinction principle and examined the ability of habituation to reduce conditioned fear reactions and prevent relapse. In a human fear conditioning paradigm, we first established one visual stimulus as a signal for an impending aversive electrical stimulation, while another visual stimulus was never followed by this stimulation. Next, the screen color changed and participants were exposed to either the visual stimuli without electrical stimulation (extinction treatment) or to the electrical stimulation without the visual stimuli (habituation treatment). Finally, the screen color changed back and the two visual stimuli were tested. Verbal ratings showed a return of conditioned shock-expectancy in the two groups, while skin conductance reactivity showed conditioned discrimination following exposures to the visual stimuli, but not following exposures to the electrical stimulation. We conclude that a habituation treatment outperforms an extinction treatment, and that shock-expectancy and skin conductance can dissociate under some conditions.

1. Introduction

Fear is an adaptive emotion that motivates the defensive reaction system in the face of danger. An optimal strategy requires the identification of valid signals of danger, which can then trigger fear and motivate preemptive defensive reactions. This is generally referred to as *fear learning* and is modeled by Pavlovian fear conditioning. In this procedure, a neutral stimulus (conditional stimulus, CS) is repeatedly followed by an aversive stimulus (unconditional stimulus, US) and results in de novo fear reactions to the CS. Arguably, as the contingency between these two events is learned, new encounters with the CS come to activate a memory representation of the US. This causes the CS to elicit a conditioned fear response (CR) with an intensity adapted to the aversiveness of this US representation (Davey, 1988). In cognitive terms, then, fear may reflect an interaction between the estimated probability and the estimated intensity of an aversive event:

$$\text{Fear} = \text{Probability x Intensity} \quad (1)$$

In conditioning terms, the estimated probability relates to the construct 'CS–US association' and the estimated intensity to the 'US memory'.

This analysis suggests that exacerbated levels of fear, as in anxiety disorders, are due to an overestimation of probability (CS–US) and/or intensity (US). Most anxiety treatments are explicitly aimed at decreasing exacerbated levels of fear (e.g., Fao and Kozak, 1986; but see Hayes et al., 2006). The most intensively studied technique in this regard is extinction, which refers to the fear reduction observed when the CS is repeatedly presented in the absence of the aversive US. The goal is to weaken/inhibit the CS–US association and hence the estimated US probability. Exposure-based treatments apply this extinction principle by exposing the anxious client to his/her feared situation in the absence of the anticipated aversive outcome (Myers, and Davis, 2007). These treatments are generally very effective in reducing fear levels in the short term (Butler et al., 1984; Rothbaum et al., 2000; Öst et al., 1993; Vlaeyen et al., 2002), but they suffer from a continuous risk of relapse (return of fear; Vervliet et al., 2013b). Increasing the long-term effectiveness of fear extinction provides the strongest challenge for clinical and pre-clinical research on anxiety. Importantly, Pavlovian fear conditioning studies have revealed that fear extinction is highly context-dependent, and that changes in the surrounding context elicit a return of fear after extinction (e.g., Vansteenwegen et al., 2005). Likewise, changes in context elicit a return of fear following successful exposure treatments (e.g., Rodriguez et al., 1999). Enhancing the generalizability of fear extinction over contexts is therefore a major challenge towards the improvement of the long-term effects of exposure-based treatments. The current study tested a novel technique aimed towards this goal.

Fear extinction research and anxiety treatments focus on weakening the CS–US association (the estimated US probability), but largely neglect the US memory itself. Nevertheless, some studies show that treatments that devalue US memories directly also reduce CS-elicited

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fear in animals (Storsve et al., 2010, 2012) and in humans (Hosoba et al., 2001; Dibbets et al., 2011). Devaluation techniques included (1) repeated exposures to the US (habituation), (2) exposures to reduced levels of the US (deflation), and (3) imagery rescripting (reappraisal). Despite successful fear reduction, however, the effects on contextual renewal are mixed. A series of US-habituation experiments in *rodents* revealed no prevention of renewal, that is, an intact return of CS-fear following a context change (Storsve et al., 2010, 2012). In contrast, combined CS-alone extinction trials with imagery rescripting did reduce renewal of fear in *humans* (Dibbets et al., 2011). Also, combined CS-alone extinction trials with US-alone habituation trials eliminated renewal of fear in humans (Vervliet et al., 2010). Together, these studies leave open the possibility that (1) targeting the US memory is more effective in humans than in rats, or that (2) mixing CS-extinction with US memory interventions is more effective than either alone. In order to solve this dual possibility, the current study was set up to investigate the sole effect of US-habituation on fear renewal in humans (analogous to the studies in rats by Storsve et al., 2010, 2012). We compared this to fear renewal after traditional extinction. Analogous to Vervliet et al. (2010), this study used a contextual renewal procedure to examine return of fear in humans. Following differential fear conditioning with two neutral CSs in context A, half of the participants received CS-alone exposure and half received US-alone exposure in context B. Finally, both CSs were presented again in context A in order to measure the amount of return of fear. The only difference with Vervliet et al. (2010) was the removal of CS-alone trials in the CS/US unpaired group of that study.

Of interest, we measured both US-expectancy ratings and skin conductance reactivity during CS presentations. We hypothesized that US-expectancy ratings are valence-free and can track the strength of the estimated US probability (CS–US association) irrespective of the estimated US intensity (US memory). Skin conductance reactivity, on the other hand, depends on both the estimated probability and intensity of the US. Therefore, we expected strongly renewed expectancy of the US in both groups, and a return of conditioned skin conductance only in the CS-exposure group.

2. Material and methods

2.1. Participants

First-year psychology students and community volunteers participated in return for payment (8 euro) or course credits. Data from two independent but identical replications of the same experiment were merged. This resulted in a total sample of eighty-seven participants (sixty-two women) with a mean age of 20.9 (SD = 4.70). Participants were randomly assigned to one of two groups. All participants gave informed consent and were aware that they could abort the experiment at any time.

2.2. Apparatus

2.2.1. Conditioned stimuli and contexts

Two geometrical shapes (square and triangle) served as conditional stimuli (CS1 and CS2) and were presented on a computer screen (Dell LCD monitor, type 1707 FPc). These shapes were grey with a black border and presented in a white frame. Stimuli slightly differed between the two experiments. In the first experiment, stimuli were darker grey and the white frame was square (versus rectangular in the second experiment). The background context was manipulated by altering the color of the background of the computer screen between yellow (RGB 255, 255, 128) and blue (RGB 0, 255, 255).

2.2.2. Unconditioned stimulus

The US was a 2 ms electrocutaneous stimulus administered to the wrist of the dominant hand. It was administered by a Digitimer DS7A constant current stimulator (Hertfodshire, UK) via a pair of V91-01-8 mm reusable Bilaney Ag/AgCL electrodes. These electrodes were filled with K-Y Jelly.

2.2.3. Skin conductance reactivity

Electrodermal activity was recorded using a skin conductance coupler manufactured by Coulbourn Instruments (model V71-23, Allentown, PA). The coupler applied a constant voltage of 0.5 V across a pair of 8 mm Ag/AgCl electrodes. These electrodes were attached to the palm of the non-dominant hand. The resulting skin conductance signal passed through a Labmaster DMA 12 bit analog-to-digital converter (Scientific Solutions, Solon, Ohio) and digitized at 10 Hz from 2 s prior to CS onset until 6 s after CS offset.

2.2.4. US-expectancy

An eleven-point scale was used to measure trial-by-trial subjective shock expectancy ratings. The scale ranged from 0 to 10 and was labelled: “certainly no shock” (0), “maybe” (5), “certain shock” (10). A left mouse click on the scale registered the corresponding position for that trial.

The stimulus sequence, stimulus presentation, ITI, and response registration was controlled by Affect 4.0 software (Spruyt et al., 2010).

2.3. Procedure

After participants gave their informed consent electrodes were fitted and the shock intensity was set to a level that was determined “definitely uncomfortable, but not painful” through a standard shock work-up procedure. Subsequently, participants were instructed that pictures of geometrical shapes would appear on the computer screen and that some of these shapes could be followed by a shock. It was further explained that the participant's task was to predict the occurrence of the shock. Next, participants were instructed how to use the expectancy ratings scale.

The experiment consisted of four phases (see Table 1). The experiment started with a non-reinforced presentation of CS1 and CS2 in order to weaken the initial orienting responses to these stimuli (pre-acquisition). During acquisition, each stimulus was presented four times in context A. CS1 was always followed by shock, CS2 never. The geometrical shapes serving as CS1 and CS2 were counterbalanced. Following acquisition, the screen color changed (context B) and participants in the CS-exposure group received traditional extinction training (eight presentations of CS1 and CS2 without reinforcement). Participants in the US-exposure group received eight presentations of the shock. Time between two shock administrations differed slightly between the two experiments, 23.43 s (range 22–26 s) in Experiment 1 and 22 s (range 20–24 s) in Experiment 2. Finally, the screen changed back to its original color (context A) and each CS was presented three times without shock. The order of context was counterbalanced; for half of the participants the order was yellow–blue–yellow, versus blue–yellow–blue for the other half.

Throughout the experiment, CS duration was always 8 s; with on average 14 s (range 12–16 s) intertrial interval (from CS offset to CS onset). The scale appeared at the bottom of the screen at CS onset. Participants used the computer mouse to control a red dot on the scale and indicate their rating. Once participants gave a rating, the scale disappeared from the screen.

2.4. Data reduction

Due to recording error, expectancy ratings and skin conductance responses (SCR) from one participant were excluded from data analysis. A second participant failed to respond within the given time