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Fear generalization in humans: Impact of feature learning on conditioning and extinction

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ABSTRACT

Little is known about the role of discrete stimulus features in the regulation of fear. This study examined the effects of feature learning on the acquisition and extinction of fear conditioning. Human participants were fear conditioned to a yellow triangle (CS+) using an electrical shock. We manipulated feature learning through differential conditioning. The nonconditioned control stimulus (CS−) was a red triangle in one group (Color-Relevant), but a yellow circle in the other group (Shape-Relevant). Next, two generalization stimuli were tested that shared the shape- or color-feature with the CS+ (a blue triangle and a yellow square). Online shock-expectancy ratings and skin conductance responding showed that the CS− determined the pattern of fear generalization: the same-color stimulus elicited more fear in Group Color-Relevant, versus the same-shape stimulus in group Shape-Relevant. Furthermore, extinguishing these two generalization stimuli had no detectable effect on fear of the CS+. These results show that fear generalization is influenced by feature learning through differential conditioning, and that exposures to different features of a stimulus are not sufficient to extinguish fear of that stimulus as a whole.

1. Introduction

The acquisition and extinction of fear receive a great deal of attention in pre-clinical research, partly because of the relevance for anxiety disorders and partly because of the availability of very good experimental procedures. The acquisition of new fears is modeled in the lab through a Pavlovian fear conditioning procedure. In a prototypical experiment in humans, a neutral stimulus (the conditioned stimulus, CS; e.g., the presentation of a geometrical figure on a computer screen) is presented a number of times and consistently followed by an unpleasant or painful stimulus (the unconditioned stimulus, US; e.g., an electrical stimulation on the forearm). Over trials, presentations of the CS ordinarily start eliciting fear reactions. Standard learning theory states that the CS–US pairings leave a memory trace in the form of a learned association between the representations of the CS and US. Henceforth, confrontations with the CS will also activate the US representation and produce fear. This simple model is highly valuable for guiding behavioral and neurological research in the domain of fear conditioning, but it is overly simplistic.

One simplification in this model is that stimuli are treated as unitary constructs. This ignores the fact that stimuli are mostly composed of discriminable features that may be represented individually in memory and acquire separate associations with the US (Rescorla, 1976). Therefore, the mere observation of newly acquired fear reactions to a CS provides little information about the exact learned association and the actual cause of fear. If a yellow triangle elicits fear after pairings with an electrical shock, is it the shape triangle, the color yellow or the combination that is associated with shock and elicits fear? This question is important, because it determines the generalization of fear to other stimuli (same-shape or same-color). Moreover, fear generalization has been implicated in anxiety disorders, potentially as an etiological factor (Lissek & et al., 2009). Insight in the factors that influence fear generalization is therefore important from an anxiety perspective. The human fear conditioning paradigm is undergoing an increased interest in fear generalization, but uniquely focused on dimensional stimulus changes (e.g., Dunsmoor, Mitroff, & LaBar, 2009; Lissek et al., 2008; Vervliet, Vansteenwegen, Baeyens, Hermans, & Eelen, 2005; Vervliet, Vansteenwegen, & Eelen, 2004). The first purpose of the present study was to examine the influence of discrete feature changes and feature learning on the conditioning and generalization of fear.

A question of equal or even greater importance concerns the generalization of fear extinction across stimuli. It has been established in many paradigms that changes in the surrounding context can trigger a recovery of the extinguished fear of a CS (Bouton, 1993; Vervliet, Craske, & Hermans, 2013). Such recovery models the frequently observed relapse after exposure-based anxiety

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treatments. However, much less is known about fear recovery due to CS changes. Vervliet et al. (2004), Vervliet et al. (2005) extinguished a generalization stimulus (GS) that was dimensionally changed from the CS (a triangle with more blunted angles) and observed return of fear when the original CS was presented at test (see Boddez et al., 2012, for a related demonstration in mouse fear conditioning). Discrete stimulus changes may well produce opposite effects than dimensional changes. Discriminable features from an extinction stimulus may *enhance* retrieval of the extinction memory when they appear in a test stimulus and thereby reduce the return of fear. Such effect would be in line with the established effects of extinction retrieval cues on contextual recovery of fear (Brooks & Bouton, 1994; Dibbets, Havermans, & Arntz, 2008; Vansteenwegen, Vervliet, Hermans, Baeyens, & van den Bergh, 2007). The current experiment provided an ideal opportunity to test this. The generalization stimuli that shared a discrete feature with the CS underwent an extinction phase, followed by test presentations of the CS. Our previous findings with dimensional changes suggest a recovery of fear at test (Vervliet et al., 2004; Vervliet et al., 2005), but the retrieval perspective predicts little or no recovery.

All participants received conditioning trials with a yellow triangle (CS+). In order to induce feature learning, half of the participants received differential conditioning with a yellow circle as CS− (Group Shape Relevant) whereas the other half received a red triangle as CS− (Group Color Relevant). Next, all participants received generalization tests with a same-shape stimulus (blue triangle) and a same-color stimulus (yellow square). We expected more fear generalization to the same-shape stimulus in group Shape Relevant, and vice versa in Group Color Relevant. Following an extinction phase with these stimuli, the original CSs were presented again and the amount of fear recovery to the CS+ was evaluated. The question was whether extinction of the fear of the features (yellow, triangle) would extinguish fear of the stimulus as a whole (yellow triangle).

2. Methods

2.1. Participants

Thirty-one students participated to earn course credits. Participants were randomly assigned to the two experimental groups (Group Color: $N = 16$; 10 females/6 males, mean age = 18.81, $SD = 0.91$; group Shape: $N = 15$; 12 females/3 males, mean age = 18.80, $SD = 1.61$). The study was approved by the ethical committee of the KULeuven (department of psychology). All participants gave informed consent and were informed that they could decline further participation at any time during the experiment.

2.2. Apparatus

An isosceles triangle (height: 36.4 mm; width: 45.5 mm) with black outlines and colored in yellow served as the CS+ for all participants. The CS− differed between the two groups: the same triangle colored in red in Group Color, and a circle (diameter: 29.2 mm) colored in yellow in group Shape. The generalization stimuli (GS) were identical in both groups: a square (height: 32.8 mm; width: 40.2 mm) colored in yellow, and the triangle colored in blue. All stimuli were presented on a computer screen, located on eye-level in front of the participant at approximately 500 mm. Shock-expectancy ratings were measured online during each stimulus presentation. A scale was presented on the bottom of the screen that was labeled from "certainly no shock" (0) through "uncertain" (5) to "certainly shock" (10). Participants could move the pointer on the scale by using the mouse, and completed their rating by clicking on the left mouse button. The scale appeared at stimulus onset and disappeared 500 ms after mouse click (in case of no click, the scale disappeared at stimulus offset). The stimulus sequence, the presentation of the stimuli and the ITIs were controlled by Affect4 software designed in our lab (free download; see Spruyt, Clarysse, Vansteenwegen, Baeyens, & Hermans, 2010). A 2 ms electrocutaneous stimulus delivered to the forearm of the left hand served as unconditional stimulus (US). It was administered by a Digitimer DS7A constant current stimulator (Hertfordshire, UK) via a pair of 11-mm Fukuda Standard AG/AGCl electrodes. The electrodes were filled with K-Y Jelly. The intensity of the shock was individually selected to a level where it was "uncomfortable but not painful". Participants were seated in an armchair in a sound attenuated room, adjacent to the experimenter's room.

Electrodermal activity was recorded using a skin conductance coupler manufactured by Colbourn Instruments (model V71-23, Allentown, PA). During skin conductance measurement, the coupler applied a constant voltage of .5 V across a pair of sintered-pellet silver chloride electrodes (8 mm), attached to the hypothenar palm of the left hand. The inter-electrode distance was approximately 7 mm. The electrodes were filled with K-Y Jelly. The resulting conductance signal was submitted 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. Participants used their right hand to record their subjective expectancy of shock by moving (and clicking) the mouse cursor over a 0–10 scale on the bottom of the computer screen. 0 was labeled Certain no shock, 5 was labeled Uncertain, and 10 was labeled Certain shock.

2.3. Procedure

Following general instructions and completion of the informed consent, participants were fitted with electrodes and were led through the work-up procedure to select a "definitely uncomfortable, but not painful" shock level. Next, participants were instructed that geometrical figures would be presented on the computer screen. They were also told that some of these figures would be followed by the shock, others would not. Finally, the expectancy scale was explained and they were told that they should try to predict the shock as accurately as possible on the basis of the figures.

The geometrical figures were always presented for 8 s; the intertrial interval varied between 13 s and 17 s, with a mean of 15 s. The experiment started with one nonreinforced presentation of the CS+ and of the CS−. During the acquisition phase, the CS+ and the CS− were presented four times each, in a randomized order with the restriction of no more than 2 consecutive identical stimulus presentations. The electrical shock was delivered at 500 ms before each CS+ offset. During the subsequent generalization test phase, the two GSs were each presented six times without the shock US. The first GS presentation was counterbalanced across participants and groups. The remaining stimulus presentations were randomized, with the restriction of no more than two consecutive identical stimulus presentations. The experiment ended with a fear recovery test phase, in which the CS+ and CS− were again presented, three times each and without shock. The first CS presentation was counterbalanced across participants and groups. The rest of the stimulus presentations were randomized, with the restriction of no more than two consecutive identical stimulus presentations.

3. Results

3.1. Online shock-expectancy ratings

3.1.1. Acquisition

Fig. 1 suggests the development of differential CS+/CS− shock-expectancy over acquisition trials. This was confirmed by a Group