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Aversive Priming: Cognitive Processing of Threatening Stimuli is Facilitated by Aversive Primes

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It would be reasonable to expect that our previous experience regarding a stimulus that predicts harm would make the subsequent identification of that stimulus easier when harm happens again. Forty-eight volunteers were submitted to both phases of this sequence of events: learning of the predictive relationship and later priming. A face with neutral expression (CS+) was paired with a moderately aversive electric shock and another (CS–) with a neutral tone. Subsequently, these two faces, as well as other known and new faces, were presented for familiarity judgments. Both the CS+ and the CS– faces were preceded by an aversive stimulus (aversive prime) in one occasion and by a neutral stimulus (neutral prime) in another. The familiarity judgment regarding the CS+ was faster after the aversive prime than after the neutral prime, but there was no difference regarding the CS–. The differential effect of the aversive prime over the CS+ and the CS– showed a significant but small correlation with the differential skin conductance response to CS+ and CS– (signal learning), and with the differential evaluation of those stimuli in terms of like-dislike (evaluative learning). The scope of these results, as well as the usefulness of this methodological model, is discussed.
Keywords: conditioning, evaluative learning, cognitive bias, stress, familiarity.

Cabe esperar que nuestra experiencia previa respecto a un estímulo predictor de un daño facilite la identificación posterior de ese estímulo cuando el daño ocurre de nuevo. Se sometió a 48 voluntarios a ambas fases de esta secuencia de hechos: aprendizaje de la relación predictiva y facilitación posterior. Se emparejó una cara con expresión neutra (EC+) con una descarga eléctrica moderadamente aversiva y otra (EC-) con un tono neutro. Posteriormente se sometieron esas dos caras, mezcladas con otras antiguas y nuevas, a juicios de familiaridad. Tanto la cara EC+ como la cara EC- iban precedidas de un estímulo aversivo (prime aversivo) en una ocasión y de un estimulo neutro (prime neutro) en otra. El juicio de familiaridad respecto al EC+ fue más rápido tras el prime aversivo que tras el prime neutro, pero no hubo diferencia en el caso del EC-. El efecto diferencial del prime aversivo sobre el EC+ y el EC- mostró una correlación significativa, aunque pequeña, con la respuesta de conductancia de la piel diferencial al EC+ y al EC- (aprendizaje de señal), y con la evaluación diferencial en términos de agrado-desagrado de uno y otro estímulo (aprendizaje evaluativo). Se discute el alcance de estos resultados y la utilidad del modelo metodológico.
Palabras clave: condicionamiento, aprendizaje evaluativo, sesgos cognitivos, estrés, familiaridad.

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In recent decades, an intensive study has been carried out on the various phenomena related to the facilitation of cognitive processing of information with emotional connotations due to the presence of other external or internal information congruent with such affective component. These phenomena appear in literature under the labels of *cognitive biases in anxiety* (see Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007), *cognitive biases in depression* (see Joormann & D'Avanzato, 2010), *affective priming* (see Klauer & Musch, 2003), *mood-congruent memory* (see Blaney, 1986; Bower, 1981), etc. Although the transfer of information between these lines of study has sometimes been poor, all these phenomena show a clear link between them: a state of anxiety, a mood or an affective prime generates biases in the processing of affectively congruent information. These biases result in an increased attention demand, allocation of processing resources in working memory, an increase in the likelihood of recall or recognition, etc.

Harm and information that predicts harm are amongst the most relevant information for an organism (see Marks, 1987). Therefore, one would expect that our experience regarding the causes of harm would help us to identify effectively, among all the surrounding information, the most likely source of that harm when harm occurs again. This would increase our speed to protect ourselves from it, for example, to escape. We would also share this adaptive mechanism with other species, which is logical if we consider that we also share a common environment, where we encounter similar problems (Dickinson, 1980). However, this does not imply that the processes involved are identical (Belzung & Philippot, 2007).

This bias in the identification of threatening stimuli would be generally adaptive (Bar-Haim et al., 2007), not only because of the speed in identifying the threat, but also due to the processing priority introduced over other stimuli present. These other stimuli would therefore interfere to a lesser extent in the evaluation of the situation and in the implementation of appropriate behaviors. A few milliseconds lead in identifying the most likely cause of harm would generate a clear advantage with respect to a situation in which all stimuli present were to be simultaneously evaluated due to an equiprobable risk allocation.

Fear learning processes and those processes related to these emotional biases share, at least partially, brain structures and functions. The amygdala, for example, plays an important role in emotional learning (including conditioning), in the affective biases of attention and perception and in the retrieval of emotionally arousing information. Other examples in which the amygdala plays an important role are the consolidation of memories with emotional content, the inhibition and regulation of emotion (including extinction of emotional learning), or the emotional determinants of social behavior (see Phelps & LeDoux, 2005; Roozendaal & McGaugh 2011).

In relation to the attention and perception biases, Phelps and LeDoux (2005) conclude that the transitory feedback from the amygdala to sensory cortical regions facilitates attention to (and perception of) stimuli that have acquired emotional properties whenever these stimuli are present again. This would allow for preferential processing of such stimuli, which would facilitate the implementation of appropriate behaviors. It is, therefore, reasonable to wonder whether attention to (and perception of) such stimuli with emotional properties is prioritized when the amygdala or other brain structures related to emotion, are activated by other emotional stimulation (e.g., Robinson, Letkiewicz, Overstreet, Ernst, & Grillon, 2011).

In the case of threats, the whole cycle could be as follows: a) a stimulus acquires threatening significance by obtaining a predictive value (signal value) in relation to an aversive stimulation (i.e., it becomes a threat), and b) a subsequent stressful situation caused by an aversive stimulation favors the identification or retrieval of that stimulus (of that threat) through attention or memory biases. In a previous paper (Huertas-Rodríguez, 1980), both stages were subjected to experimental control. An artificial word (CS+) was paired with a moderately aversive electric shock and another artificial word (CS–) was paired with a neutral tone, using a differential conditioning procedure. Afterwards, the participant was asked to count backwards in threes and then was presented ten times with a tone, now aversive, and ten times with an electric shock, now neutral. Upon receiving the tone or the shock, the participant should stop counting back and say the first word that came to mind of the two presented during the conditioning phase (CS+ or CS–). The probability of responding with the CS+ word was greater after the presentation of an aversive tone than after presentation of a neutral shock. In a subsequent work (Huertas-Rodríguez, 1985), it was found that the probability of response with the CS+ word in the presence of the aversive stimulus was greater when the aversive and neutral character of the stimuli were not crossed during the recall phase, that is, when the shock remained aversive and the tone was neutral. In summary, the probability of recalling an artificial word previously associated with an aversive stimulus would increase in the presence of that same aversive stimulus and would also increase, although not to the same extent, in presence of other aversive stimuli. Initially, these findings were interpreted in terms of reversibility of the S-R relationship, but from a cognitive point of view, one could say that the aversive stimulus from the recall phase operates as a prime that favors retrieval of the word previously associated with an aversive stimulus (Huertas-Rodríguez, 1991).

In later work (Huertas et al., 2010), it was found that recognition of a face previously paired with an aversive stimulus was facilitated by the presence of this aversive stimulus to a greater extent in CC genotype carriers of the C957T *DRD2* SNP than in T-allele carriers. This finding is consistent with data demonstrating the important role that the dopaminergic system plays in emotional processes related to fear conditioning (Pezze & Feldon, 2004; Londsdorf & Kalisch, 2011), as well as in procedural learning (Huertas, Bühler, Echeverry-Alzate, Giménez, & López-Moreno, 2012) or in implicit learning (Karabanov et al., 2010). This would highlight the relationship between certain emotional processing mechanisms, certain genetic variations, and certain disorders that have been associated with both those emotional processes and those genetic variations. Individual adaptability (and the corresponding inadaptability) would therefore depend on the interaction of mechanisms at the genetic, epigenetic and environmental level (Wolf & Linden, 2012).

In first instance, this paper aims to improve the methodological model used in previous studies and to replicate the aversive-priming effect under these new conditions. In the three articles cited (Huertas et al., 2010; Huertas-Rodríguez, 1980, 1985), episodic memory tests (recall and recognition) were used, which may be sensitive to strategic decisions (the participant may discover what is expected of him and act accordingly). Furthermore, none of these articles entirely dissociated the prime's aversiveness from its physical nature (shock or tone). This was either because the physical form may have exerted an additive priming effect on aversiveness (the shock is aversive and the tone is neutral both during the conditioning and the priming phase), or because it could have exerted a subtractive effect (the aversive stimulus in the priming phase is the tone and the neutral one is the shock while, during the conditioning phase, the aversive stimulus was the shock and the neutral stimulus was the tone).

In this paper, a familiarity judgment task will be used during the priming phase, instead of using recognition or recall tasks, as familiarity has often been considered the result of an automatic processing prior to recognition (see Mandler, 1980; Wagner, Gabrielli, & Verfaellie, 1997; Yonelinas, 2001, 2002). In addition, an asynchrony in the onset of *prime–target* stimuli (SOA) of 190 milliseconds will be used. Both measures are intended to minimize the potential impact of strategic decisions (see Carter, Hough, Stuart, & Rastatter, 2011; Wiese, 2011). The physical form of the primes will be balanced. That is, half of the participants will be presented with a shock of moderate intensity as an aversive prime and with a tone of low intensity as the neutral prime, while the other half of the participants will have an intense tone as the aversive prime and a shock close to the threshold as a neutral prime. In this way, this research intends to establish the net effect of the aversiveness of the prime, regardless of whether its physical form matches that of the unconditioned stimulus in the prior conditioning phase or not.

This paper also aims to explore the possible association of aversive priming with the signal learning and evaluative learning that result from prior conditioning (Baeyens, Eelen, van den Bergh, & Crombez, 1989; Levey & Martin, 1975). As mentioned above, it is expected that aversive priming will share brain structures and functions with signal and evaluative learning; therefore, an association between aversive priming and these two forms of learning is to be expected.

Method

Participants

Initially, 48 university students took part in the experiment. This number was determined in aid of balancing and counterbalancing stimuli. Seven of the original participants answered "no" to the familiarity judgment in the priming phase with respect to CS+ or CS– in one or more of the four critical trials. Therefore, these participants were replaced by another seven university students with similar characteristics, which were subjected to the same conditions (sequences of stimuli, etc.) than those they were replacing. Thus, 48 participants (38 women) aged between 19 and 24 years (M = 20, SD = 1.2) were suitable for data analysis. All participants performed the experiment voluntarily and signed an informed consent form. For some of them, participation in the experiment and the subsequent explanation of its objectives was considered a three-hour practical class, alternative to other possible practicals. The recruiting system and the experimental procedure have been approved by the Ethics Committee of the Psychology Faculty (Universidad Complutense de Madrid).

Apparatus, stimuli and response recording

The experiment was carried out in the Psychology Faculty of the Universidad Complutense de Madrid. The apparatus, stimuli and procedure used in this study overlap with those described in Huertas et al. (2010). The experiment had four phases: habituation, conditioning, priming and evaluation in terms of pleasure-displeasure. The first three phases of the experiment were performed individually; the last phase was performed in group.

During the first three phases, the participant was seated in a partially soundproof and dimly lit room (3.18 x 2.20 x 2.10 m). The devices were installed in an adjacent room. The two rooms were connected through a one-way mirror and an intercom. The participant sat at a table to which a white screen of 44 x 57 cm was attached by means of a flexible arm and on which images were projected. The screen was located at an approximate distance of 110 cm from the participant and around the height of his/her head. The projected image was 22 x 30 cm in dimension.

The images were presented using a KODAK CAROUSEL S-AV 2050 projector. The tones were generated using a Nuova Elettronica LX-740 oscillator and were amplified through an integrated stereo TA-F117R Sony amplifier. During the conditioning phase, tones were presented through a loudspeaker situated in front of the participant, at 150 cm. During the priming phase, tones were presented binaurally through headphones. Electric shocks were generated using a Mark 100 (Farrall Instruments, INC., Grand Island, Nebraska) stimulator, which was battery-powered and optically isolated from the computer. Shocks were administered through concentric Tursky-type electrodes, attached to the volar surface of the forearm. An IBM compatible personal computer, equipped with a PCL-812PG Multi-Lab card and a PCLD -785 relay board (both from Advantech Co., Ltd.) was used to present stimuli and record skin conductance responses (SCRs) and response times (RTs). The software used to control both the stimuli presentation and response recording had been developed in the Technical Service Department of the Psychology Faculty of the Universidad Complutense de Madrid.

The SCRs were recorded through Beckman-type electrodes (Ag-AgCl) of 8 mm in diameter filled with a 0.05 molar NaCl gel. They were attached using adhesive collars and Velcro tape to the palmar surface of the second phalanx of the first and second fingers of the non-dominant hand. The signal was amplified using a Coulbourn S71-22 bioamplifier (Coulbourn Instruments, Whitehall, PA, USA) and sampled at 50 Hz. During the conditioning phase, the data from the 3 seconds before and 16 seconds after the appearance of the images were stored. During the priming phase, data between four seconds before and eight seconds after were stored. A purpose-built console, which had two short-travel buttons horizontally aligned, 1 cm apart from each other, and marked with the words “YES” and “NO”, was used to register the RTs. The console was placed on the table of the experimental room during the priming phase.

A 1000 Hz tone was applied. When the tone was used as a neutral stimulus, its intensity was fixed by the participant, following the instruction “you must hear it clearly but you must not find it annoying at all”. When the tone was used as an aversive stimulus, it had a fixed intensity of 105 dB (A). The intensity of the electrical shock was determined by the participant in both cases. When the shock was used as an aversive stimulus, the instruction given was “it is necessary that you find the shocks clearly uncomfortable but not painful”. When it was used as a neutral stimulus, the statement was “it is important that you do not find the shocks uncomfortable at all, let me know as soon as you barely notice them”. During the conditioning phase, shocks were applied to the dominant forearm, whereas in the priming phase they were applied to the non-dominant forearm.

To set the intensities subject to instructions for both the tone and the shock, the participant was presented with the stimuli with increasing intensity starting from zero until the participant indicated the stimulus had reached the level corresponding to the instruction given. After setting the intensities, the participant was advised that they could be changed at any given time if he/she thought it was necessary, so that the subjective intensities were consistent with the instructions received. In every rest period of the experiment, the participant was asked about the intensity of tone and shock, to ensure that they maintained the expected subjective intensity. If necessary, the intensities were modified.

Four faces with a neutral expression from the Ekman and Friesen (1976) set (numbers 21, 41, 65, 99) were used to be paired with the aversive shock (CS+) and the neutral tone (CS–) during the conditioning phase. Two of them were male faces and the other two were female faces. Half of the participants were presented with the two male faces as the CS+ and CS– and with the two female as faces they should simply get familiar with throughout the conditioning phase. The other half of the participants were presented with the opposite. Also, the specific face used as CS+ or as CS– was balanced between subjects. Another 10 faces with a neutral expression, taken from Ekman and Friesen’s set (numbers 6, 13, 28, 33, 47, 56, 72, 83, 92, 110) were added to the previous ones in the priming phase, as unknown faces. Ten faces with a happy expression and another 10 with an angry expression, taken from the same set (1, 3, 14, 18, 22, 25, 29, 32, 34, 38, 42, 44, 57, 61, 66, 69, 93, 96, 101, 105), were used as faces to be evaluated in the evaluative learning test (evaluation phase). Four of those happy faces and four of those angry faces corresponded to the four faces with neutral expression used in the conditioning phase.

The last phase of the experiment, the evaluation phase, was conducted in a (10 x 7 m) room with a long table and a capacity for 30 people, seated on either side of the table. At the head of the table, there was a white screen (2 x 1.5 m) on which the face images (70 x 50 cm) were projected, using a projector identical to the one used in previous phases. There was an approximate distance of 30 cm between participants. Each participant was given a 7-page booklet, in which they could evaluate three faces per page. To evaluate each face, the expressions *sad-happy, angry-fearful, unpleasant-pleasant, forced expression-natural expression* appeared at the ends of four 100 mm lines, 10 mm apart from each other. Above each of those sets of four scales, a number corresponding to the serial onset of the faces appeared. The order of the four evaluation scales for each face varied between participants but remained constant for the same participant.

The reason for using happy and angry faces in the evaluation phase rather than the neutral faces of the habituation, conditioning and priming phases, was to help separate the evaluation phase (presented to participants as an independent investigation) from the other three phases and, in this way, minimize the ‘demand characteristics’ effect, a common problem in evaluative learning research. This same objective was the reason for using four scales, even though only the pleasant-unpleasant dimension would be used.

Procedure

As mentioned above, the experiment consisted of four phases: habituation, conditioning, priming and evaluation in terms of pleasure-displeasure. The first three took place individually whereas the fourth phase was carried out in two groups. The habituation phase was designed to familiarize participants with the faces that would be used during the conditioning phase and to measure the initial SCR to CS+ and CS–. The conditioning phase was designed to achieve differential conditioning with respect to CS+ and CS–, and to verify differential SCR to these stimuli. The priming phase aimed to determine whether aversive priming occurred. The evaluation in terms of pleasure-displeasure phase was aimed at measuring evaluative learning.

Before starting the experimental procedure, the participant was asked to read and sign the informed consent, the contents of which were made known to him/her from the recruiting stage. The participant was advised he/she could abandon the experiment at any time. Afterwards, the areas where the SCR electrodes were to be placed were cleaned with distilled water and the SCR and shock electrodes were attached. Once the electrodes were prepared, the initial shock and tone intensities (aversive and neutral, respectively) were determined using the method previously described.

Habituation and conditioning phases. The participant was informed that he/she would be presented with four faces, each of them several times. He/she was advised that one of these faces would sometimes be followed by a shock; another face would sometimes be followed by a tone and that, except in those cases, faces would be presented alone. Afterwards, the habituation and conditioning sets of trials started, without pause or further instructions between these two phases. During the habituation phase, an unreinforced presentation of CS+, CS– and the other two faces was carried out. These two additional faces were to be used later in the priming phase as familiar faces, in addition to the CS+ and CS–. During the conditioning phase, eight presentations of CS+ accompanied by the aversive shock, eight presentations of CS– accompanied by the neutral tone , three presentations of CS+ alone and another three of CS– alone (test trials), and four presentations of each of the other two faces presented in the previous phase took place. The exposure time to each face was eight seconds and the duration of the shock and the tone was 200 ms each. The interval between the appearance of the face and the onset of shock or tone was three seconds. The interval between trials (from start to start) varied randomly between 24s and 28 s.

The habituation-conditioning phase was organized into six blocks of trials with a total of 34 trials, and a single 3-minute break after the 20th trial. These blocks went unnoticed by the participants, since there was no pause between them. The first block (habituation) consisted of a presentation of each of the four faces alone. The second block consisted of two presentations of CS+ followed by the aversive shock and two presentations of the CS– followed by the neutral tone. Blocks 3, 4 and 5 consisted of two presentations of CS+ followed by the aversive shock, two presentations of the CS– followed by the neutral tone, a presentation of the CS+ alone, a presentation of the CS– alone and a presentation of each of the other two faces alone for each block. Block 6 consisted of a presentation of each one of these last two faces alone. The order of presentation of the faces alone and of the sequences CS+/shock and CS–/tone were randomized within each block with the restriction that none of the faces appeared more than three consecutive times.

Priming phase. Before starting this phase, the shock electrodes were changed from the dominant to non-dominant arm, so that the participant could press the buttons more efficiently during the task. The intensity of the shock was set again. In the case of the half of participants for which the shock should be aversive for this phase, the intensity of the shock set at the beginning of the experiment was maintained. The shock was presented once to verify its subjective intensity was correct, otherwise, it was corrected. In the case of the participants for whom the shock should be neutral for this phase, the procedure described in the *Apparatus, stimuli and response recording* paragraph was followed. Afterwards, several more shocks at this level were presented to the participant so as to familiarize him/her with the shock at this intensity.

Then, the participant was informed that he/she would be presented with a series of faces and he/she had to indicate as quickly as possible, but trying not to make mistakes, if the face was familiar or not. He/she was advised that the faces would sometimes be preceded by a shock or a tone. The participant was also told that the shock and tone acted as "noise" and that any face could be preceded by a tone, a shock or neither. Finally, headphones were placed over the participant's ears. Participants in the aversive tone group were warned that the tone would be more intense in this phase while those participants in the neutral tone group were told that the tone would remain at the same intensity as in the first part of the experiment.

The decision on whether the face was familiar or not was registered by pressing one of the two buttons on the console: 'yes' or 'no'. The face would disappear when a button was pressed. If more than three seconds lapsed after the appearance of the face without any button being pressed, the face disappeared automatically. The interval between the onset of the prime and the onset of the target (SOA) was 190 ms. The duration of the prime (shock or tone) was 180 ms. The interval between trials (from start to start) varied randomly between 19 and 21 seconds.

During the priming phase, two presentations of CS+ and two presentations of CS– were made, each one preceded by the aversive prime one of the times and the neutral prime the other. These four critical sequences took place in the

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9th, 13th, 17th and 20th trial. There were eight different presentation orders for these sequences, corresponding to the eight possible combinations that met the requirement of alternating presentations of CS+ and CS–, in order to reduce autopriming. Each of these combinations was applied to six participants (three out of the subgroup in which the aversive prime was the shock and three out of the subgroup in which the aversive prime was the tone). Alternating with these trials, seven presentations of each of the other two faces shown during the phases of habituation and conditioning and 10 presentations of new faces were made during this phase. Four of these presentations were preceded by an aversive prime, seven were preceded by a neutral prime and six were not preceded by any prime whatsoever. Therefore, the aversive prime was used in only 6 out of 21 trials. It was never used in the trial immediately preceding the critical presentations with neutral primes. In this way, it was intended to minimize the effects of nonspecific aversive priming, unrelated to the trial. The phase ended with a presentation of the CS+ and CS– not preceded by any prime, where the presentation order was counterbalanced between subjects.

After the first four trials of this phase, the participant was asked if he/she had any difficulty in performing the task and if the shock and the tone remained within the established subjective intensities. After trial 14, there was a 3-minute break, in which the participant took part in a geometric image retention task, so as to prevent the participant from "rehearsing" faces and therefore reducing autopriming. The experimental session ended with a post-experimental interview in which, among other things, the participant was asked to estimate the level of displeasure-pleasure of the shock and the tone in both parts of the experiment on a scale of -100 to +100.

Evaluation phase. The participants were summoned in two groups to explain the goals of the research, as it had been pointed out when they were recruited. The period of time lapsed between the previous three phases and this phase ranged between 5 and 35 days, depending on the day the participants had completed the previous phases, performed individually. Before this explanation took place, the participants were asked to help classify a series of faces with emotional expressions. They were informed that the aim of such task was to typify a set of faces using a Spanish sample for use in further research. The reason behind allowing some time to lapse between the three previous phases and this phase, coupled with the presentation of this evaluation phase as a task outside the main investigation, was to minimize the 'demand characteristics' effect on evaluations, which is a major problem in evaluative learning research, as previously mentioned. The participants were also advised that it was possible that some of the faces had appeared in the previous experiment, but they must try to focus only on the face they were looking at to make the most accurate assessment possible. They were asked to mark with a vertical line the point on each scale that best fit the sensation that the face caused them and to respond with their first impression. In this way, it was intended that the evaluations were not strategic and as spontaneous as possible. Each face was projected individually. When all participants had completed their assessment of that face, the next face was projected.

Each face used as CS+ and CS– was presented twice. This time, instead of the neutral expression used in previous phases, a happy expression of that same face was used in one of the presentations and an angry expression in the other, as has been previously mentioned. Alternating with these faces, another 16 faces, half showing a happy expression and the other half an angry expression, were presented. Four of them (two happy and two angry) corresponded to the other two faces presented during the habituation and conditioning phases. The critical faces corresponding to the CS+ and CS– appeared, within the sequence of presentations, in the 4th, 10th, 15th and 18th position or in the 6th, 9th, 12th and 16th position, according to the pair of faces that each participant had seen as CS+ and CS–. The faces corresponding to the CS+ alternated with those corresponding to CS–. The sequence of presentation of faces was fixed, but since the neutral face that had operated as CS+ for one participant had operated as CS– for another, the positions at which faces with expressions corresponding to the CS+ and CS– appeared were counterbalanced.

Analyses

A range correction, dividing each one by the maximum specific response for that participant and multiplying the result by 100, was applied to the SCR data (PC SCR). The resulting values were transformed using the square root to normalize their distribution (SQRT [1+PC SCR]). In relation to the RTs, a logarithmic transformation was performed to normalize the data distribution. However, the means are shown in milliseconds to facilitate interpretation. None of the RT values deviated more than three SD away from the grand mean of those data.

In the case of the evaluations, for each data, the distance in millimeters between the vertical line marked by the participant on the pleasant-unpleasant analog scale and left end of the scale was measured, thus converting that distance into a score that could range between 0 and 100. The participant's average rating for the face with a happy expression and the face with an angry expression corresponding to the neutral face used as CS+ was taken as his/her evaluation for CS+. The same was applied for CS– evaluation. Four of the participants did not complete this last task correctly and therefore their data were not included in the analysis of this variable.

For analysis of the SCR of the conditioning phase, a repeated measures ANOVA (IBM SPSS Statistics 19 for Windows, SPSS Inc., Chicago, IL) was used with the type of CS (+ or -) and the test trial (1, 2, 3) as within-subject factors . For the data analysis of the priming task, a repeated measures ANOVA was also used with the prime (aversive, neutral) and CS (+, -) as within-subject factors. Pairwise comparisons were performed using repeated measures *t*-tests. We used one-tailed tests for comparisons for which there was a directional hypothesis and two-tailed tests for the rest. The correlation between the effect of priming (difference between the RT to CS+ and the RT to the CS– after the aversive prime in the familiarity judgment), the differential SCR for CS+ and CS– and the differential evaluation of these stimuli were analyzed using Pearson correlations.

Results

Shock and Tone Aversiveness. The shock should be aversive and the tone neutral during the conditioning phase. During the priming phase, half of the participants were presented with an aversive shock and a neutral tone, whereas the other half was presented with a neutral shock and an aversive tone. Two aversiveness indexes were taken: the SCRs and the displeasure-pleasure estimations obtained in the post-experimental interview. In relation to SCRs, the response to the aversive shock was greater than the response to the neutral tone during the conditioning phase (D = 5.19; $t(47)$ = 24.76; p < .001). During the priming phase, the response to the aversive shock was greater than the response to the neutral tone (D = 4.49; t (23) = 11.28; p < .001), and the response to the aversive tone was greater than the response to the neutral shock (D = 0.71; t (23) = 1.91; p < .03), according to the subgroup. Regarding the displeasure-pleasure estimations, participants considered the aversive shock more unpleasant than the neutral tone for the conditioning phase (D = 69.27; $t(47)$ = 15.54; p < .001). For the priming phase, they considered the aversive shock to be more unpleasant than the neutral tone (D = 51.25; t (23) = 8.83; p < .001) or the aversive tone more unpleasant than the neutral shock (D = 67.86; $t(23)$ = 8.39; p < .001), according to the subgroup. Therefore, the aversive shock generated a greater SCR than the neutral tone during the conditioning phase and was rated as more unpleasant. Similarly, the aversive prime (shock or tone) generated a higher SCR than the neutral one during the priming phase and was also rated as more unpleasant.

Signal learning. Firstly, the SCR to the CS+ was compared with the SCR to the CS– during the habituation trial, prior to conditioning (Figure 1). The difference was not significant ($t(47)$ = .19; p < .852). This would indicate that CS+ and CS– generated similar responses initially. Afterwards, a CS (+, –) x acquisition test-trial (1, 2, 3) ANOVA was performed. Only the CS main effect was found to be significant ($F(1, 47)$ = 102.45; p < .001; η^2 p = .69). The response to CS+ was greater than the response

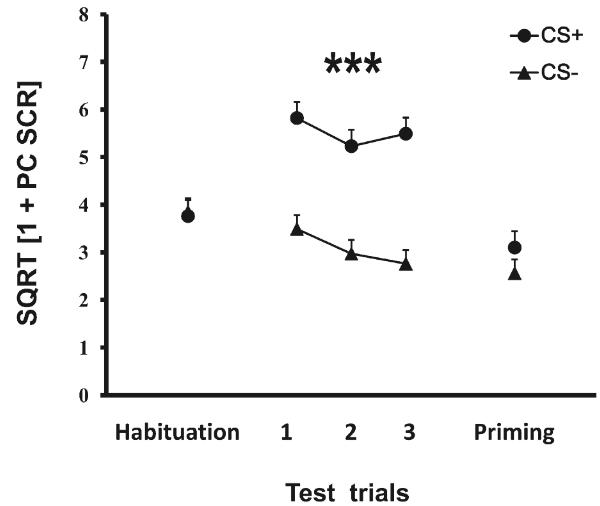

Figure 1. Signal Learning. Magnitude of the skin conductance response (SCR) to the CS+ and CS- in the trial of the habituation phase, in the three test trials of the conditioning phase and the test trial of the priming phase. SQRT [1 + PC SCR]: square root of 1 plus the percentage of the skin conductance response relative to the maximal response of that participant. *** p < .001.

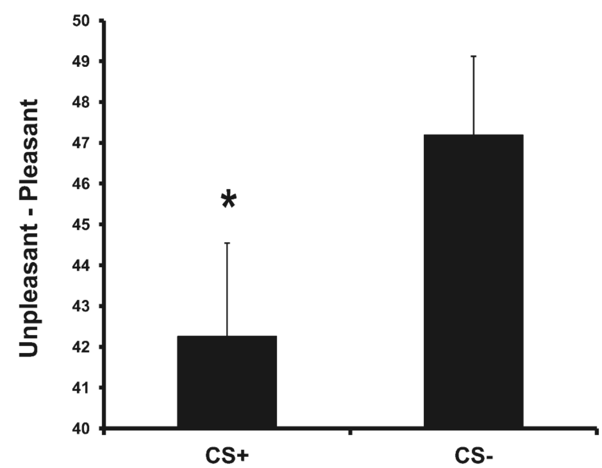

Figure 2. Evaluative Learning. Average evaluation in terms of displeasure-pleasure, on a scale of 0-100, of the happy and angry faces corresponding to CS+ and CS–. * p < .05

to CS– in each of the three test trials (p < .001). This indicates that differential conditioning occurred. Finally, the SCR to the CS+ was compared with the SCR to the CS– for the test trials after the priming phase. The difference was found to be significant ($t(47)$ = 2.59; p = .007), indicating that, after the priming phase, a differential SCR was maintained.

Evaluative learning. Regarding the evaluations of the fourth phase of the experiment (Figure 2), the CS+ evaluation (average score given for happy and angry faces corresponding to the CS+ face on the unpleasant-pleasant scale) obtained a lower score (closer to the unpleasant end

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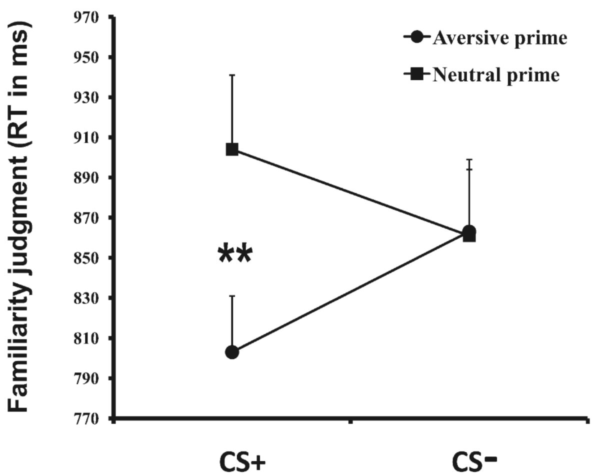

Figure 3. Aversive priming. RT in milliseconds of the familiarity judgment relative to the CS+ and CS–, when either stimulus is preceded by the aversive and the neutral prime. ** $p < .01$ relative to the difference between the aversive prime/CS+ and neutral prime/CS+ conditions.

of the scale) that the CS– evaluation ($t(43) = 1.89$; $p = .032$). That is, participants rated CS+ as more unpleasant than CS. Therefore, the results indicate that there was differential evaluative learning to CS+ and CS–.

Priming. It was expected that the familiarity judgment related to the CS+ should be faster after the aversive prime that after the neutral prime. In contrast, no significant differences were expected to be found between the RT of both familiarity judgments with respect to CS–. Therefore, the hypothesized effect should be indicated by the prime x CS interaction (Figure 3). Firstly, a prime (aversive, neutral) x CS (+, -) ANOVA was performed. An independent measures factor relative to the stimulus (shock, tone) that operated as aversive prime during the priming phase was added to the model in order to control the possible effect of this variation between subjects.

The prime x CS interaction was found to be significant ($F(1, 46) = 6.25$; $p = .016$; η^2 p = .12). In contrast, the interaction prime x CS x stimulus operating as aversive prime was found to be non-significant ($F(1, 46) = .25$; $p = .621$). Therefore, pairwise comparisons were made on the whole set of data. Such paired comparisons, relative to the significant prime x CS interaction, showed that the RT was lower in the aversive prime/CS+ condition than in the neutral prime/CS+ condition ($t(47) = 3.00$; $p = .002$). The RT was also lower in the aversive prime/CS+ condition than in the aversive prime/CS– condition ($t(47) = 1.82$; $p = .037$), and in the aversive prime/CS+ condition than in the neutral prime/CS– condition ($t(47) = 1.87$; $p = .034$), as hypothesized. The difference between the neutral prime/CS+ and the neutral prime/CS–conditions was found not to be significant ($t(47) = 1.33$; $p = .189$). The difference between the neutral prime/CS+ and the aversive prime/CS– conditions was also found not to be significant ($t(47) = 1.04$; $p = .303$), as well as the difference between the aversive prime/CS– and the neutral prime/CS– conditions ($t(47) = .03$; $p = .974$). In summary, when the face previously associated with an electric shock was preceded by an aversive prime, the familiarity judgment was faster than in any of the other three conditions. There were no significant differences between any other pair of conditions.

The difference between the familiarity-judgment RT in the aversive prime/CS+ condition and in the aversive prime/CS– condition correlated significantly with the difference between the SCR to the CS+ and to the CS– in the test trial 3 ($n = 48$; $r = -.253$; $p = .041$). That is, the greater the differential SCR at the end of the conditioning phase, the higher the aversive priming. Also, the difference between the familiarity-judgment RT in the aversive prime/CS+ condition and in the aversive prime/CS– condition correlated significantly with the difference between the CS+ and CS– evaluations in the evaluation phase ($n = 44$; $r = .281$; $p = .032$). That is, the greater the difference of CS+ and CS– evaluations, the greater the aversive priming. However, the correlation between the SCR differential to the CS+ and to the CS– in test trial 3 of the conditioning phase and the difference between the CS+ and CS– evaluations in the evaluation phase was not found to be significant ($n = 44$; $r = .121$; $p = .217$).

Discussion

The results of this study were as expected. The familiarity judgment relative to a face with a neutral expression (the CS+), which had previously acquired a predictive value over an aversive stimulus, was faster after an aversive prime than after a neutral prime. Conversely, the type of prime (aversive or neutral) did not affect the speed of the familiarity judgment of other face with a neutral expression (the CS–) that had previously acquired a predictive value over a neutral stimulus. The difference between the RT to the CS+ and the RT to the CS– following an aversive prime in the familiarity judgment showed a positive, albeit small, correlation, both with signal learning (reflected in the differential SCR to CS+ and CS–), and with evaluative learning (reflected in the differential evaluation in terms of pleasure-displeasure of the CS + and CS–).

Therefore, an aversive priming effect was obtained. The data are consistent with previous studies (Huertas et al., 2010; Huertas-Rodríguez, 1980, 1982). Even despite the fact that a familiarity judgment task and a prime-target SOA of 190 ms were used, which would reduce the likelihood of strategic decisions (see Carter et al., 2011; Wiese, 2011; Yonelinas, 2001, 2002). Moreover, this occurred despite having balanced the physical form of the aversive and neutral prime, which would allow showing the prime's aversiveness net effect, regardless of whether its physical nature is identical or not to the unconditioned stimulus from the pre-conditioning phase.

Hence, the full cycle has been completed experimentally: a) a stimulus acquires threatening significance due to its predictive value over an aversive stimulation, and b) the presence of a later aversive stimulation favors the identification of that stimulus through attention or memory biases.

These results differ partly from those in other works concerning the role that aversive stimulation plays in the retention of stimuli associated to it and in the attention to (and perception of) these stimuli when the aversive stimulation is again present (Cf. Roozendaal & McGaugh 2011; Wolf, 2009). Regarding retention, Cahill, Gorski, & Le (2003), for example, have found that the application of aversive stimulation favors the consolidation of an emotional memory, even if the stimulation is applied some time after that emotional experience. In fact, the amygdala's activity during exposure to emotional pictures correlates positively with the subsequent recall of these images (Cahill et al., 1996). Our data are consistent with those results. By contrast, stress appears to impair retrieval of emotional information from memory, at least after long retention periods (Domes, Heinrichs, Rimmele, Reichwald, & Hautzinger, 2004; Kuhlmann, Kirschbaum, & Wolf, 2005). Psychosocial stress, for example, seems to impair retrieval of emotional memories (e.g. Tollenaar, Elzinga, Spinhoven, & Everaerd, 2008). It also appears to impair processing in working memory, essential in the identification of stimuli (see Roozendaal & McGaugh, 2011). Therefore, our data contradict these latter results.

However, a question arises on the functional value of this difficulty in retrieving emotional information from long-term memory, or in processing it in working memory, under stressful situations. Roozendaal and McGaugh (2011) consider that this temporary impairment could be due to the prioritization of the processing and consolidation of new emotionally relevant information. However, this prioritization would make no sense if it were done at the expense of ignoring potential threats related to that stressful situation. Indeed, data from the extensive research on cognitive biases in anxiety indicate that stressful situations favor the detection and identification of potential threats (real or imagined) (see Bar-Haim et al., 2007). Consequently, one might think that the deterioration in the recovery of information from memory that is produced by stress would occur in relation to the information not relevant in the current context (whether emotional or not). Our data, as well as data from research on cognitive biases in anxiety, support the idea that stress favors the processing of emotional information relevant to the current situation. In summary, stress seems to favor attention focusing and prioritization of processing of the information relevant to the threatening situation, relegating any other competing information.

This mechanism (adaptive under normal circumstances) may also be involved in some psychopathological disorders. For example, one of the criteria established by the DSM-IV (*Diagnostic and Statistical Manual of Mental Disorders*, 4th ed.; American Psychiatric Association, 1994) for the diagnosis of specific anxiety disorders is the persistent recovery of the traumatic event in the form of images, thoughts, dreams, illusions, or flashbacks (acute stress disorder and posttraumatic stress disorder), or the presence of recurrent and persistent thoughts or images that are experienced as intrusive or inappropriate (obsessive-compulsive disorder), or excessive, difficult to control, worry (generalized anxiety disorder). This intrusive information is often vivid and very detailed from a sensory point of view (Brewin, Gregory, Lipton, & Burgess, 2010).

In the case of acute stress and posttraumatic stress disorders, several studies suggest, in fact, an association between the extreme stress of a traumatic experience and subsequent changes in memory functioning (Pitman, 1989; Elzinga & Bremner, 2002). These changes would include an increase of the likelihood of flashbacks and intrusive phenomena related to the experienced trauma, as a result of a subsequent increase in arousal (Witvliet, 1997). This retroactive effect of arousal would occur even if the increase is caused artificially: by hyperventilation (Hopwood & Bryant, 2006, Nixon & Bryant, 2005), or through various products (Bremner et al., 1997; Kellner, Levengood, Yehuda, & Wiedemann, 1998, Jensen et al., 1997; Rayney et al., 1987, Southwick et al., 1993).

This increase of intrusive phenomena would not be exclusive of anxiety disorders. It would also occur in other disorders where anxiety is present, for example, in schizophrenia. In the case of schizophrenic patients, stress appears to increase the risk of hallucinations (Freeman & Garety, 2003). Stress also seems to increase drug craving, which leads to the appearance of images and thoughts related to drugs (Sinha, 2009; Sinha, Shaham, & Heilig, 2011).

With respect to the methodological aspects, the experimental procedure used in this study presents advantages over other models. Our results hold, as has been previously mentioned, apparent similarities with those obtained in other research, such as those related to cognitive biases in anxiety (see Bar-Haim et al., 2007) or those on affective priming (see Klauer & Musch, 2003; Spruyt, De Houwer, Hermans, & Eelen, 2007). However, in both types of investigations, the history of learning of the emotional information on which the biases take place is generally unknown. Consequently, the variations over the likelihood or speed of processing of that emotional information, which priming yields, could be affected by other variables related to that target information, such as familiarity, salience, etc. (see Dewitte, De Houwer, Koster, & Buysse, 2007).

Using the experimental procedure followed in this study, the learning history is controlled (the faces used as CS+ and CS– were unknown to the participants before starting the

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experimental session), the same initial salience is guaranteed (the face that operates as CS+ and the face that operates as CS– are balanced between participants), the familiarity towards CS+ and CS– is similar (the number of trials in which they have appeared is the same), etc. That is, the target information, both the emotional one with negative content (the CS+) and the one that has no negative content (the CS–), with which it is compared, differ only in that the former has been associated with aversive stimulation and the second with neutral stimulation during the conditioning phase. Therefore, this methodological model may be useful to study the psychological and physiological processes involved in this type of biases in depth.

Our data also indicate that the aversive priming effect correlates moderately with signal and evaluative learning (Baeyens et al., 1989; Levey & Martin, 1975). As it has been said above, empirical evidence indicates that the processes involved in emotional biases and those involved in emotional learning share structures and physiological functions such as the amygdala (see Phelps & LeDoux, 2005; Roozendaal & McGaugh 2011) or the dopaminergic system (Pezze & Feldon, 2004). Therefore, it is not surprising that aversive priming is more marked for people who show a greater autonomic response to target (CS+), or who evaluate that stimulus as being more negative. These individual differences could be simply the result of circumstantial variables such as the unconditioned-stimulus' actual aversiveness for each participant, which would determine the intensity of signal learning, of evaluative learning and of the priming. However, they may also arise from genetic variations. Huertas et al. (2010), for example, have found that CC genotype carriers of the C957T SNP, associated with dopamine D2 receptors, showed greater aversive priming to the CS+ and also higher differential conditioning.

Since the main objective of this research was the analysis of aversive priming, as mentioned above, some methodological decisions such as those relating to task order or stimuli sequencing were conditioned by that aim. This reduced the possibility of analyzing the other dependent variables recorded and, therefore, the possibility of drawing conclusions other than those described. For example, it was not advisable to ask the participants to rate the faces that were to operate as CS + and CS– in terms of pleasure-displeasure before the start of the conditioning phase, in order to establish the initial evaluations. This could affect the subsequent conditioning and priming tasks. Therefore, it is not possible to know whether the differential evaluation of the faces corresponding to the CS+ and CS– in the last phase (and consequently the correlation between the differences in these evaluations and the priming effect) is due to the change, during the conditioning phase, of the hedonic tone of the CS+, of the hedonic tone of the CS– or of both. Furthermore, the priming task itself could produce new learning, which could affect the evaluations of both stimuli at the posterior evaluation phase. For example, in the priming phase, CS– was preceded once by the aversive prime and CS+ was preceded once by the neutral prime, which could have a counter-learning effect. Empirical evidence suggests that, in this sense, evaluative learning occurs even in backward conditioning trials (see Hoffman, De Hower, Perugini, Baeyens, & Crombez, 2010). Therefore, it is possible that, in the absence of a priming phase between the conditioning phase and the evaluation phase, the difference between the evaluations of CS+ and CS– would be greater.

In conclusion, the presence of an aversive prime seems to facilitate the cognitive processing of a face previously associated with an aversive stimulus, which is reflected in a faster familiarity judgment. This aversive priming effect positively correlates with signal learning, reflected in the conditioned SCR, and with evaluative learning, reflected in the evaluation in terms of pleasure-displeasure.

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