Biological Psychology 92 (2013) 17–25

Contents lists available at SciVerse ScienceDirect

Biological Psychology

journal homepage: www.elsevier.com/locate/biopsycho

Individual differences in predicting aversive events and modulating contextual anxiety in a context and cue conditioning paradigm

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ARTICLE INFO

Article history:
Received 1 March 2011
Accepted 1 February 2012
Available online 10 February 2012

PsycINFO classification:
2343
2360
2560

Keywords:
Conditioning
Cue
Context
Trait anxiety
Attentional control
Startle

ABSTRACT

Deficient fear conditioning leads to maladaptive contextual anxiety as predicting danger is a key factor in regulating anxiety. A virtual reality conditioning task was used to evaluate cue learning and contextual anxiety with fear-potentiated startle and subjective fear in two experiments. In Experiment 1, failure to condition to a cue resulted in a constant state of context anxiety (subjective fearfulness and startle). Trait anxiety was unrelated to learning cue contingencies but the participants who failed to learn scored lower on a self-report measure of attentional control. Part of the group that learned the cue contingency failed to deduce safety of the context and hence did not reduce their contextual anxiety. Experiment 2 specifically focused on isolating this process and demonstrated an inverse association between trait anxiety and adaptive modulation of contextual anxiety. In conclusion, predicting threat aids in but not automatically implies successful regulation of contextual anxiety. High trait anxiety may increase risk of deficient modulation of contextual anxiety.

1. Introduction

The fear conditioning paradigm has been used as an experimental model for mechanisms that may lead to excessive fear. Factors underlying individual differences in conditioning may prove relevant for understanding individual differences in developing different anxiety disorders (Mineka and Oehlberg, 2008). In addition, differences in cue conditioning on the one hand and context conditioning on the other hand may be related to vulnerability for different types of anxiety disorder (Grillon, 2002b). The pathway to excessive anxiety that is usually proposed is through excessively intense conditioned responding (e.g., Otto et al., 2007). This may be the case in some forms of pathological anxiety such as phobias. On the other hand, successfully predicting danger and developing conditioned responses to stimuli that cue danger is an adaptive process in guiding behavior. Indeed, previous studies demonstrated that not acquiring a conditioned response to a cue that predicts threat leads to increased contextual anxiety (Baas et al., 2008; Grillon, 2002a). Failure to condition to cues in the environment may thus lead to more generalized chronic anxiety, perhaps modeling the states of less specific, future oriented, anxiety present in anxiety disorders other than phobias.

Classical fear conditioning provides a laboratory model for these processes in which a conditioned stimulus (CS) is paired with an aversive stimulus (unconditioned stimulus, US) such as a shock. Not learning the contingency leads to the entire situation or context being the best predictor of threat, resulting in a chronic state of apprehension (Baas et al., 2008; Grillon, 2002a; Seligman and Binik, 1977). A previous study (Baas et al., 2008) demonstrated that awareness of the contingency between light and shock was closely associated with a reduction in contextual anxiety in the threat context in the absence of the threat signal. In aware subjects, startle and subjective fear were reduced in the intervals between the presence of the CS when threat was actually imminent. An important question with respect to vulnerability for contextual anxiety and for potential therapeutic intervention is which factors determine whether people learn to adapt their responses in the presence and absence of (potential) predictors for threat. This article describes two experiments in which factors leading to successful adaptive responding are assessed by looking at the interplay between cue and context conditioning.

Research has largely focused on individual differences in expression of the conditioned response (Fredrikson and Georgiades, 1992; Lonsdorf et al., 2009; Otto et al., 2007). A study looking at

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doi:10.1016/j.biopsycho.2012.02.001

individual differences in whether or not adaptive conditioned responses were acquired suggested that differences in trait anxiety may play a role (Chan and Lovibond, 1996), though only marginally significant effects of trait anxiety were found in attempts to replicate this finding (Baas et al., 2008; Grillon, 2002a). One aim of Experiment 1 was to test personality factors that differentiate between subjects who succeed in predicting threat and those who do not in a larger sample. Alternatively, the marginally significant effects of trait anxiety found earlier might be an indication that not trait anxiety per se but a related dimension is predictive of individual differences in contingency learning. Individual differences in attentional processes may provide another explanation for why some people pick up on predictors of threat whereas others do not. Associative learning theories consider stimuli that are not the focus of attention ineffective in acquiring associative strength with respect to an outcome (Mackintosh, 1975; Pearce and Hall, 1980). Therefore, attentional factors may underlie the differentiation between conditioning or not. Several lines of research suggest that anxiety is associated with differences in attentional processes (Eysenck et al., 2007; Mathews and MacLeod, 1985). The Attentional Control Scale (ACS) introduced by Derryberry and Reed correlates inversely with trait anxiety (Derryberry and Reed, 2002; Healy and Kulig, 2006; Massar et al., 2010). In Experiment 1 this scale was used to assess effects of individual differences in strategic allocation of attention on conditioning, which may affect acquisition of conditioned responses by impacting the attention that is being paid to the CS.

Learning about signals of threat and safety is important. However, individual differences in the inhibition of fear in the presence of safety signals have been suggested to be key in the development of anxiety disorders (Davis et al., 2000). Accordingly, Lissek et al. (2005) argued that one particular deficit in individuals with anxiety disorders in conditioning paradigms may be the inability to inhibit their fear response during periods of relative safety. The safety signal hypothesis (Seligman and Binik, 1977) suggests that the ability to use information on predictors of threat to deduce that the absence of these predictors is safe is an important mechanism in reducing chronic anxiety. The phenomenon of context conditioning was described by Pavlov as an initial generalized acquisition of conditioned properties to the environment. Consequent reinforcement of a 'single definite and constant stimulus' will result in the appearance of a specific conditioned response to this stimulus, and the generalized responding to the environment disappears. This was theorized to be due to a gradually developing inhibition of responding to the context when the specifically conditioned stimulus is absent (Pavlov, 1927). Variability in this latter process may thus account for individual differences in contextual anxiety.

Experiment 1 investigated factors that determine whether cue contingencies are learned. The hypothesis was in line with earlier findings (Baas et al., 2008) that participants who did not show differential shock expectancy during the presence and absence of the CS would display continuously elevated fear in the shock context as evidenced by measures of subjective and physiological (startle reflex) responses. The group of participants who would fail to condition was hypothesized to be associated with high trait anxiety and/or relatively low attentional control. Experiment 2 was aimed at testing the role of trait anxiety in the expression of adaptive responses to signals of threat and safety in a situation in which awareness of the cue contingency was achieved in all individuals by more explicit instructions regarding the contingencies.

2. Methods Experiment 1

2.1. Participants

Students at Utrecht University, The Netherlands, were recruited from a database ($n = 37$ of $N = 445$) containing Spielberger Trait Anxiety Inventory data (Dutch translation, Van der Ploeg et al., 1979) and by means of flyers on campus ($n = 24$). In total, 61 participants participated in the study. Exclusion criteria were: past or current psychiatric disorders, hearing or vision problems, and use of psychotropic medication. Participants gave informed consent approved by the University Medical Hospital Utrecht medical–ethical review committee, and were compensated for their time with €7.50/h. Four participants were excluded from the analyses due to unreliable performance. The remaining 57 consisted of 43 women and 14 men (mean age 20.8; SD = 1.8 years).

2.2. Stimuli

The experiment consisted of movie clips recorded from virtual environments from VR Worlds (Psychology Software Tools, Inc.). Contexts in this experiment were the first floor of a house in a suburban area and an apartment in a high-rise in a down town area, connected by a street and metro scene. Conditioned stimuli consisted of an 8-s duration increase in background illumination ('lights on'). This created four conditions: Shock context lights off (context) and on (cue) and safe context lights off and on. See Baas et al. (2008) and supplementary online Fig. S1 for more details and samples of pictures from the contexts. Pre-recorded movies were played on a computer screen and markers for events in the movies were registered in the physiological data record and used for time-locked triggering of startle probes and shocks. Startle probes were 50-ms duration white noise bursts presented through headphones with 98 db(A) intensity. Intensity of shock stimuli was individually titrated towards a level of 'highly annoying but not painful' in a work up consisting of at most 7 shocks of increasing intensity. Shocks were 750-ms trains of 2-ms pulses administered to the inside of the left wrist at 200 Hz presented by a constant current stimulator (DS7A, Digitimer Ltd.) co-terminating with the 8-s CS.

2.3. Questionnaires

Participants filled out computerized Dutch translations of the trait portion of the State-Trait Anxiety Inventory (Spielberger, 1972; Van der Ploeg et al., 1979) and the Attentional Control Scale (Derryberry and Reed, 2002; translated in Dutch by M. Morren, see Massar et al., 2010).

2.4. Design conditioning experiment

Each of 14 experimental blocks consisted of one long or two shorter visits to the shock and safe contexts, with four 8-s CS presentations in each context (see the next paragraph for more details). A block started with three startle probes for reflex habituation presented while the participant was watching the introductory part of each block displaying a ride on the metro. Visits to contexts were made by exiting the metro at either the down town or suburban area and a visit to the corresponding place (apartment or house). Transition between contexts consisted of moving back to the metro station. For sake of time transitions did not include a metro ride, instead the screen blacked out after entering the station, and then the exit was at either the same or the other location. During this 40-s street scene two startle probes were presented to maintain habituation. Orders of visits to shock and safe contexts were counterbalanced between blocks and subjects. Assignment of shock context (house or apartment) was counterbalanced across subjects.

The comparison between physiological responses during the shock and safe contexts may be compromised when shocks are presented just prior to measurement of these responses in the shock context only. Therefore, 8 out of 14 blocks were test blocks, in which only the CS right before leaving the shock context was reinforced (blocks 2 & 3, 6 & 7, 10 & 11, 13 & 14). To prevent predictability of the shock reinforcements by only reinforcing the last CS, each block contained a visit to one context that included four CSs and lasted 90 s, while the visit to the other context was divided into two shorter visits (including one or three CSs and lasting 30 and 70 s, respectively). In test blocks only the last CS per visit was reinforced. Therefore, one or two CS presentations were reinforced with a shock depending on whether the shock context was visited once or twice. Test blocks were always presented in pairs containing one with a single and one with a double visit to the shock context. The average rate of reinforcement in test blocks was thus 37.5%, which yielded a poor rate of learning in a pilot study. Therefore in additional training blocks (6) three out of four CSs were reinforced. Physiological data from these training blocks were not included in graphs and analyses. A startle probe was presented during three out of four CS presentations in each context and three startle probes were presented in each context in the absence of a CS. Intervals between startle probes were between 12 and 20 s.

2.5. Subjective reports

Between blocks, ratings of fearfulness were collected by means of computer visual analog scales (VAS), and shock expectancy was assessed with forced choice questions. In the VAS and forced choice questions, ten representative scenes (screen shots taken from the movie clips) were used for each of the four conditions (shock context lights off (context) and on (cue) and safe context lights off and on). For the VAS scale, two repetitions of each condition with different pictures drawn randomly were presented after each block (1–14). The question was: 'How fearful do you feel in this situation?' (anchors: '*Not at all fearful of shock*' [0] and '*Very fearful of shock*'