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The Effect of Positive Affect on Extinction Learning and Return of Fear

A dissertation submitted in partial satisfaction of the requirements for the degree Doctor of
Philosophy in Psychology

by

Tomislav Damir Zbozinek

2018

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ABSTRACT OF THE DISSERTATION

The Effect of Positive Affect on Extinction Learning and Return of Fear

by

Tomislav Damir Zbozinek

Doctor of Philosophy in Psychology

University of California, Los Angeles, 2018

Professor Michelle Craske, Chair

Although exposure is an effective treatment for anxiety disorders, its efficacy is limited, and efforts are being made to enhance its overall effectiveness. This dissertation evaluates one potential method of optimizing extinction learning and exposure therapy: increasing positive affect during extinction. The effect of positive affect on learning is discussed in regards to various components of learning, including attention, encoding, rehearsal, consolidation, retrieval, and stimulus appraisal. These effects are then discussed specifically with regard to extinction learning and exposure therapy. Study 1 evaluated whether positive affect is associated with lower rates of reacquisition, or, an increase in fear following re-pairings of the conditional stimulus (CS+) and unconditional stimulus (US; e.g., electric shock) after extinction. Results showed that higher positive affect before and after extinction was associated with less CS+ fear during reacquisition as measured by skin conductance arousal and US expectancy. Study 2 used a mood

induction to assess its effects on spontaneous recovery, long-term extinction learning, and reacquisition. This study found null results of mood induction on fear. Study 3 evaluated the effects of mood induction on generalization of extinction learning. The results showed that positive mood induction before extinction resulted in less self-report fear of a novel generalization stimulus at test. The results of all three studies are discussed with relevance to exposure therapy.

The dissertation of Tomislav Damir Zbozinek is approved.

Michael S. Fanselow

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Michelle Craske, Committee Chair

University of California, Los Angeles

2018

Dedication

I would like to dedicate this dissertation to my family, my advisors, and everyone who supported me in accomplishing this.

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This dissertation includes an adaptation of the following publication: Zbozinek, T. D., & Craske, M. G. (2017). Positive affect predicts less reacquisition of fear: relevance for long-term outcomes of exposure therapy. *Cognition and Emotion*, 31(4), 712-725. Tomislav Zbozinek, MA was the principal investigator and was responsible for the study's design, data collection, analysis, and write-up. Michelle Craske, PhD provided critical feedback regarding the design and implementation of the study, as well as the manuscript.

This dissertation also includes the following publication: Zbozinek TD, Craske MG (in press). The role of positive affect in enhancing extinction learning and exposure therapy for anxiety disorders. *Journal of Experimental Psychopathology*. Tomislav Zbozinek, MA was the principal investigator and was responsible for the literature review and write-up. Michelle Craske, PhD provided critical feedback regarding the manuscript.

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Publications

1. **Zbozinek, T.D.**, & Craske, M.G. (in press). The role of positive affect in enhancing extinction learning and exposure therapy for anxiety disorders. *Journal of Experimental Psychopathology*.
2. **Zbozinek, T.D.**, & Craske, M.G. (2017). Positive Affect Predicts Less Reacquisition of Fear: Relevance for Long-Term Outcomes of Exposure Therapy. *Cognition and Emotion*, 31(4), 712-725.
3. **Zbozinek, T.D.**, Holmes, E., & Craske, M.G. (2015). The Effect of Positive Mood Induction on Reinstatement Fear: Relevance for Long Term Outcomes of Exposure Therapy. *Behaviour Research and Therapy*, 71, 65-75.
4. **Zbozinek, T.D.**, Hermans, D., Prenoveau, J.M., Liao, B., & Craske, M.G. (2015). Post-extinction conditional stimulus valence predicts reinstatement fear: Relevance for long-term outcomes of exposure therapy. *Cognition and Emotion*, 29(4), 654-667.
5. Craske, M.G., Treanor, M., Conway, C., **Zbozinek, T.**, & Vervliet, B. (2014). Maximizing Exposure Therapy: An Inhibitory Learning Approach. *Behaviour Research and Therapy*, 58, 10-23.
 - a. (Dutch) Vervliet, B., Depreeuw, B., Treanor, M., Conway, C., **Zbozinek, T.**, & Craske, M.G. (2014). Exposuretherapie maximaliseren: een benadering volgens het inhibitorisch-leermodel. *Gedragstherapie*, 47, 296-339.

- b. (German) Pittig, A., Stevens, S., Vervliet, B., Treanor, M., Conway, C.C., **Zbozinek, T.**, & Craske, M.G. (2015). Optimierung expositions-basierter Therapie: Der Ansatz des inhibitorischen Lernens. *Der Psychotherapeut*.
 - c. (Spanish) Torrents-Rodas, D., Fullana, M.A., Vervliet, B., Treanor, M., Conway, C., **Zbozinek, T.**, & Craske, M.G. Maximizar la terapia de exposición: Un enfoque basado en el aprendizaje inhibitorio. *Revista de Psicopatología y Psicología Clínica*. 1(1).
 - d. (French) Philippot, P., Dethier, V., Vervliet, B., Treanor, M., Conway, C., **Zbozinek, T.**, & Craske, M.G. (2015). Maximiser la thérapie par exposition: une approche basée sur l'apprentissage. *Revue Francophone de Clinique Comportementale et Cognitive*.
 - e. (Italian) Toso, E., Craske, M.G., Treanor, M., Conway, C., **Zbozinek, T.**, & Vervliet, B. (2016). Massimizzare la terapia di esposizione: Un approccio basato sull'apprendimento inhibitorio. *Cognitivismo clinic* 13(2), 103-133.
6. Rose, R., Buckey, J., **Zbozinek, T.D.**, Glenn, D., Motivala, S., Cartreine, J., Craske, M.G. (2013). A Randomized Controlled Trial of a Self-Guided, Multimedia, Stress Management and Resilience Training Program. *Behaviour Research and Therapy*, 51, 106-112.
 7. **Zbozinek, T.D.**, Rose, R., Wolitzky-Taylor, K., Sherbourne, C., Sullivan, G., Stein, M., Roy-Byrne, P., & Craske, M.G. (2012). Diagnostic Overlap of Generalized Anxiety Disorder and Major Depressive Disorder in a Primary Care Sample. *Depression and Anxiety*, 29, 1065-1071.

Presentations

1. **Zbozinek, T.D.**, & Craske, M.G. (2016, November). *The Effect of Positive Mood Induction before Extinction on Reacquisition of Fear*. Paper presented at the annual convention of the Association of Behavioral and Cognitive Therapies, New York, NY.
2. **Zbozinek, T.D.**, Glenn, D., Minor, T., & Craske, M.G. (2014, May). *The Effects of Positive Mood Induction on Conditional Stimulus Valence in Reducing Reinstated Fear*. Paper presented at the annual convention of the Association for Psychological Science, San Francisco, CA.
3. **Zbozinek, T.D.**, Davies, C., Arch, J., & Craske, M.G. (2013, April). *Relationship between Positive Affect, Negative Affect, and Psychophysiology in an Anxious, Treatment-Seeking Sample*. Presentation at the annual convention of the Anxiety Disorders Association of America, La Jolla, CA.

General Introduction

General Introduction is adapted from: Zbozinek, T.D., & Craske, M.G. (in press). The role of positive affect in enhancing extinction learning and exposure therapy for anxiety disorders. *Journal of Experimental Psychopathology*.

Exposure is well-established as an effective therapeutic strategy for anxiety disorders (Hofmann & Smits, 2008; In-Albon & Schneider, 2007). However, rates of remission following completion of cognitive-behavioral therapy (CBT), which includes exposure therapy, are approximately 50% (Loerinc, et al., 2015). Hence, methods are needed to optimize the effectiveness of exposure therapy (Craske, et al., 2014). Greater understanding of the mechanisms responsible for exposure therapy may inform methods that enhance long-term treatment gains.

The inhibitory learning approach is one method of optimizing exposure that is derived from principles of fear extinction (Craske, et al., 2014). In a Pavlovian conditioning model, a neutral stimulus (the conditional stimulus, CS+, such as a neutral picture) is followed by an aversive stimulus (the unconditional stimulus, US, such as an electric shock). After a number of such pairings, the neutral CS+ will come to elicit anticipatory fear (or, a conditional response, CR). The CR is intended to protect the individual from experiencing the US or prepare the individual for the US (Bolles & Fanselow, 1980). This often takes the form of flight, fight, or freeze; the precise behavior depends on the species and proximity to the US (Fanselow, 1988). For example, a rat that detects a predator (CS+) from a distance may freeze (CR) in order to prevent being attacked (US). On the other hand, if the predator is about to attack, the rat may fight back and vocalize (CR) to prevent itself from being harmed (US). For humans, the CR is

fear, which may take the form of fight, flight, or freeze. For example, an individual who is afraid of heights (CS+) for fear of injury or death (US) may experience fear while looking out the window of a tall building and possibly flee to the ground floor.

Within a Pavlovian conditioning approach, the inhibitory learning model states that the original CS+/US association learned during fear conditioning is not erased during extinction, but rather is left intact as new, secondary inhibitory learning about the CS+/US develops, specifically that the CS+ no longer predicts the US (e.g., Bouton, 1993; Bouton & King, 1983). Inhibitory learning is considered to be central to extinction (Bouton, 1993; Miller & Matzel, 1988; Wagner, 1981), although additional mechanisms, such as habituation, are likely to be involved (Myers & Davis, 2007). Research into the neural mechanisms underlying fear extinction support an inhibitory model, since the amygdala, which is particularly active during fear conditioning (Shin & Liberzon, 2010), appears to be inhibited by cortical influences identified as occurring from the medial prefrontal cortex as a result of extinction learning (Greco & Liberzon, 2016; Maren & Holmes, 2016; Milad, et al., 2007, 2009).

Bouton (1993) proposes that after extinction, the CS+ possesses two meanings: its original excitatory meaning (CS+/US) as well as an additional inhibitory meaning (CS+/No-US). Therefore, even though fear subsides with enough trials of the CS+ in the absence of the US, retention of at least part of the original association can be uncovered by various procedures, with each one showing a continuing effect of the original excitatory association after extinction. These effects include spontaneous recovery, or an increase in conditional fear proportional to the passage of time from the end of extinction to the next time the CS+ is encountered. Renewal is an increase in conditional fear when the CS+ is encountered in a context different from the extinction context. Reacquisition is an increase in conditional fear when the CS+ is re-paired

with the US. Lastly, reinstatement is an increase in conditional fear when the US is presented in isolation of the CS.

The violation of an individual's expectations regarding the frequency or intensity of aversive outcomes when confronting the CS+ is central to the inhibitory learning approach to exposure (Craske et al., 2014). This strategy derives from the premise that mismatch between expectancy and outcome is critical for new learning (Rescorla & Wagner, 1972) and for the development of inhibitory expectancies that will compete with excitatory expectancies. The model posits that the more the expectancy can be violated by experience, the greater the inhibitory learning that will result. This model attempts to improve upon habituation-based models, which emphasize fear reduction during exposure, because neither fear reduction nor fear levels at the end of exposure predict long-term outcome from extinction or exposure in rodents or human samples (Baker et al., 2010; Culver et al., 2012; Kircanski et al., 2012; Plendl & Wotjak, 2010; Prenoveau et al., 2013; Rescorla, 2006).

Additionally, increased levels of anxiety have been shown to increase fear to safety signals or difficulty to discriminate between danger cues and other cues (e.g., CS-, which predict the absence of the US). This has been shown in individuals with high trait anxiety (Boddez, et al., 2012; Meulders, Meulders, & Vlaeyen, 2014) and in clinical samples (Craske, Waters, et al., 2008; Lissek, et al., 2009). Higher fear responding during safety signals has been shown to be a specific risk factor of anxiety disorder onset compared to depressive disorder onset (Craske, et al., 2012). Thus, efforts made to increase safety learning may also yield benefits for individuals with anxiety disorders.

This dissertation explores a novel method of optimizing extinction – and, in turn, exposure therapy – that can be additive and complementary to the inhibitory learning approach:

increasing positive affect during extinction and exposure. “Affect” refers to mental states involving evaluative feelings (Gray & Watson, 2007). Positive affect refers to pleasant feelings of good or liking, whereas negative affect refers to unpleasant feelings of bad or disliking. Positive and negative emotions refer to affective states with specific objects that reflect an underlying appraisal of a given situation (e.g., fear, joy; Clore & Huntsinger, 2007). Positive affect has been shown to enhance many forms of learning and memory – including encoding, rehearsal, and retrieval (e.g., Kiefer, et al., 2007). Positive affect can also increase positive valence of stimuli (Zbozinek, Holmes, & Craske, 2015) and modulate attention by either broadening or narrowing attention (Gable & Harmon-Jones, 2008; Huntsinger, Isbell, & Clore, 2014). Therefore, positive affect may play an important role in enhancing the effects of exposure therapy by enhancing extinction learning.

This dissertation has three primary aims: 1) To review the literature on the effects of positive affect on learning and memory, 2) To propose pathways through which positive affect enhances extinction learning and exposure, and 3) to test the effects of positive affect during extinction on spontaneous recovery, reacquisition, and generalization of extinction learning.

1.1 Attention and Positive Affect

Initially, it was thought that positive affect broadens attention (Derryberry & Tucker, 1994; Fredrickson, 2001; Fredrickson & Branigan, 2005; Gasper, 2004; Gasper & Clore, 2002; Rowe, et al., 2006), whereas negative affect narrows attention (e.g., Compton, 2000). More recent data suggests that the effect of mood on attention is not this simple. According to the “motivational intensity” model, the motivational aspect of emotion is a major factor in determining whether attention narrows or broadens during positive and negative affect (Harmon-

Jones, Price, & Gable, 2012). Specifically, both positive and negative emotions can narrow or broaden attention depending on their motivational drive (Gable & Harmon-Jones, 2008, 2010, 2011; Harmon-Jones & Gable, 2009; Harmon-Jones, Price, & Gable, 2012). Highly motivational emotions that encourage approach towards (e.g., anger, desire, enthusiasm) or avoidance of (e.g., disgust, fear) a stimulus serve to narrow attention. Emotions that do not motivate approach or avoidance (e.g., amusement, contentment, sadness) broaden attention. An example of narrowed attention with a goal-directed positive emotion (e.g., desire) would be detecting a desirable object (e.g., a cupcake), development of a goal (e.g., eat the cupcake), and narrowing of attention upon the desirable object until the goal is accomplished (e.g., the cupcake is eaten). Narrow attention is adaptive in that it facilitates focus of attention upon accomplishing a goal, whereas broad attention would distract from goal completion. Thus, according to the motivational intensity model, the positive or negative valence of emotions does not determine breadth of attention; rather, high goal-directedness narrows attention, whereas low goal-directedness broadens attention. It is therefore possible for both positive and negative emotions to narrow and broaden attention.

Another theory, the “affect-as-cognitive-feedback” model (Huntsinger, Isbell, & Clore, 2014), also attempts to elucidate the effects of positive and negative affect on breadth of attention. The affect-as-cognitive-feedback model – an extension of the “affect-as-information” model – generally states that affect endows mental processes (e.g., attention) with value (i.e., the goodness-badness of something) (Huntsinger, Isbell, & Clore, 2014). Positive affect serves to evaluate current mental processes as valuable, whereas negative affect serves to evaluate current mental processes as not valuable. If a mental process is deemed valuable, it will continue; if it is deemed as not valuable, it will decrease until a more suitable mental process is employed. In the

context of an existing state of narrowed attention, the affect-as-cognitive-feedback model predicts that positive affect will maintain narrowed attention because positive affect gives value to narrowed attention; conversely, negative affect will lead narrow attention to broaden because negative affect devalues narrowed attention (Huntsinger, Isbell, & Clore, 2014). Similarly, in the context of an existing state of broadened attention, positive affect will maintain broadened attention whereas negative affect will lead to narrowed attention. In support of the affect-as-cognitive feedback model, Huntsinger, Clore, and Bar-Anan (2010) found that when individuals were primed to have broad attention, positive mood induction maintained broad attention, and negative mood induction generated narrow attention. The same was true when narrow attention was primed: positive mood induction maintained narrow attention, and negative mood induction generated broad attention.

Attempts to determine which model – the motivational intensity model or the affect-as-cognitive-feedback model – has greater predictive and construct validity have been methodologically inadequate for reasons such as failure to induce goal-directed, motivational positive emotions (Gasper, 2004; Isbell, et al., 2013; Kuhbandner et al., 2011; Rowe, et al., 2007) or failure to target attention (Bodenhausen, et al., 1994; Isbell, et al., 2013). Thus, it is unclear how the above two models relate or which of the models is a more accurate conceptualization of the relationship between positive affect, negative affect, and breadth of attention.

1.2 Attention and Extinction

The Rescorla-Wagner model (Rescorla & Wagner, 1972) is a widely accepted and influential learning model in which error-correction is purported to account for much of fear conditioning. Though it does not perfectly predict all phenomena of learning (e.g., CS pre-

exposure effect), it accurately predicts many aspects of Pavlovian learning (Miller, Barnet, & Grahame, 1995). The Rescorla-Wagner model states that the greater the difference between an expected outcome and the actual outcome, the more learning occurs. For example, presentation of a US on CS trials when the CS is not judged to be a predictor of the US results in more learning about the CS than if the US did not occur. This is expressed in the Rescorla-Wagner formula: $\Delta V_A = \alpha_A \beta (\lambda - \Sigma V)$. In this formula, A is a given CS (i.e., CS_A). ΔV_A is the change in associative conditioning of CS_A with the US (e.g., electric shock), α_A is the salience of CS_A , β is the learning rate parameter for the US, λ is the maximal level of learning determined by the intensity of the US, and ΣV is the sum of associative strength of all CSs.

Mackintosh (1975) expanded on the Rescorla-Wagner model by focusing on CS salience. Increased salience of the CS promotes attention towards the CS. Attention that is narrowly focused upon the CS and minimized to other stimuli will maximize learning of the CS. Broad attention would delay learning of the CS. While α_A is constant in the Rescorla-Wagner model, α_A changes as learning occurs in the Mackintosh model. For Mackintosh (1975), the more the CS is correlated with the US, the more attention will increase to the CS (i.e., α_A will increase). This is reflected in the Mackintosh (1975) formulas: α_A will increase if $|\lambda - V_A| < |\lambda - V_X|$, where X is the summed associative strength of all other CSs besides CS_A . This model has gained much support (Lawrence, 1952; Reid, 1953; Dias, Robbins, and Roberts, 1996; Dopson, Esber, and Pearce, 2010; Durlach & Mackintosh, 1986; George and Pearce, 1999; Mackintosh and Little, 1969; Shepp & Eimas, 1964; Shepp & Schrier, 1969; Trobalon, Miguelez, McLaren, & Mackintosh, 2003).

Conversely, Pearce and Hall (1980) stated that the more association a CS has with a US, the less associable that CS will be with other outcomes (e.g., absence of US, different intensities

of the US). According to this theory, stimuli that accurately predict the events that follow them will receive little attention, whereas stimuli that inaccurately predict these events will be paid considerable attention. They proposed that the purpose of attention is not to encourage focus on stimuli that are accurate predictors of reinforcement. Instead, the purpose of attention is to promote rapid learning about a stimulus, and therefore there is little purpose in attending to a stimulus when learning is complete. In the Pearce and Hall (1980) formula $\alpha_{n+1} = |\lambda_n - V_n|$, if CS_A is presented on trial n , the amount of attention, α_A , paid to it on trial $n+1$ is a function of the intensity of the US (λ_n) minus the associative strength of CS_A on trial n . The second formula, $\Delta V_A = \alpha_A \beta \lambda$, shows the relationship between attention and learning (similar to the Rescorla-Wagner (1972) model). The Pearce and Hall (1980) formula was first demonstrated in a study that was ironically intended to provide evidence in support of the Mackintosh (1975) model (Hall & Pearce, 1979) and has gained support in many other studies (Haselgrove, Esber, Pearce, and Jones, 2010; Hogarth, Dickinson, Austin, Brown, and Duka, 2007; Kaye and Pearce, 1984; Swan & Pearce, 1988).

Despite the ample support for both models, they offer opposing predictions. Pearce and Mackintosh (2010) reviewed both models and their relationship with the Rescorla and Wagner (1972) model. They concluded that all three models are valid and postulate that the most comprehensive model includes a built-in error-correction learning mechanism as well as two attentional learning mechanisms. Thus, Pearce and Mackintosh (2010) propose the following formula: $\Delta V_A = \alpha_A \sigma_A \beta (\lambda - \Sigma V)$. In this formula, A is a given CS. ΔV_A is the change in associative conditioning of CS_A with the US (e.g., electric shock), α_A is the salience of CS_A from the Mackintosh model, σ_A is the salience of CS_A from the Pearce-Hall model, β reacquisition is the learning rate parameter for the US, λ is the maximal level of learning determined by the intensity

of the US, and ΣV is the sum of associative strength of all CSs. Le Pelley (2004) and Pearce and Mackintosh (2010) suggest that the value of α_A be restricted to .05 and 1 and the value of σ_A be restricted to .5 and 1. This formula suggests that greater attention towards CS_A (i.e., $\alpha_A \sigma_A$) results in greater learning (i.e., ΔV_A). Though the three models predict differences in attention as a result of learning, all models predict that attention is necessary for learning.

Based on the updated Pearce and Mackintosh (2010) formula, narrowly focused attention upon the CS will increase α_A . This will increase the speed of learning to the CS because the CS is more salient. Conversely, broadened attention will decrease the speed of learning to the CS because other stimuli (e.g., context, neutral stimuli) become a source of attention along with the CS. Attention is especially important during extinction. Attention that is narrowly focused upon the CS and minimized to other stimuli will maximize learning that the CS does not predict the US. Broad attention during extinction would delay learning of the CS.

Another potential benefit of maintaining narrowed attention on the CS during extinction involves contextual effects. Unlike excitatory CS/US associations (i.e., acquisition of fear), inhibitory CS/No-US associations (i.e., extinction) are context-dependent (Bouton, 1993). Consequently, following extinction in one context, conditional fear will increase when the CS is encountered in a different context (i.e., renewal of fear; Bouton & Bolles, 1979). The scope of attention during extinction may influence renewal of fear. Narrow attention on the CS likely reduces encoding of surrounding contextual information and thereby decreases contextually bound extinction learning compared to broad attention. In contrast, broad attention may increase encoding of contextual information during extinction, resulting in more awareness that a new context is not the extinction context. Hence, broadened attention may lead to more contextual renewal of fear than narrowed attention during extinction.

Attention is likely to be broad prior to extinction, as a broad focus is the default mode of attention (Huntsinger, Isbell, & Clore, 2014). According to the “affect-as-cognitive-feedback” and “motivational intensity” models, anxiety experienced during extinction is likely to narrow attention. Specifically, the “affect-as-cognitive-feedback” model suggests that attention will narrow because negative affect conveys low value on broad attention and instead promotes narrow attention; the “motivational intensity” model suggests that attention will narrow because fear is a highly goal-oriented emotion (i.e., fight, flight, or freeze in response to the feared stimulus to defend oneself). As previously described, positive affect that is goal-oriented (e.g., desire) narrows attention, whereas positive affect that is not goal-oriented (e.g., amusement) broadens attention (e.g., Gable & Harmon-Jones, 2008). Both theories also predict that inducing a goal-oriented positive emotion would narrow attention: the affect-as-cognitive-feedback model (Huntsinger, Isbell, & Clore, 2014) predicts that positive affect would reinforce the already-existing narrow attentional scope that occurs during fear or anxiety, whereas the motivational intensity model (Gable & Harmon-Jones, 2008) predicts that goal-oriented positive affect narrows attention. Since anxiety as well as goal-oriented positive emotion narrow attention, the question that arises is whether the combination of anxiety and goal-oriented positive emotion results in even further narrowing of attention. If so, and if possible, then the combination of both emotions may be ideal for extinction.

1.3 Attention and Exposure

The implication for exposure therapy (the clinical proxy of extinction) is that new learning will be enhanced by narrowing of attention upon the feared stimulus (Craske et al., 2014). More specifically, narrowed attention should enhance learning that the feared stimulus is

not predictive of an aversive outcome. For purposes of implementation in an exposure session, clients should be informed in advance of the details of the exposure. This will presumably increase anticipatory anxiety, which would narrow attention according to both the motivational intensity model and affect-as-cognitive feedback model. Once the exposure plan is determined, a positive mood induction with high motivational intensity could be employed. This would maintain narrow attention according to the affect-as-cognitive-feedback model, and may narrow attention even further according to the motivational intensity model. Furthermore, the context-specificity of the new learning in exposures could be reduced, leading to greater generalization of extinction learning when the previously feared stimulus is encountered in a context different from the exposure context. By extension, positive affect (particularly goal-directed positive affect) may augment the long-term effects of exposure to the degree that attention is further narrowed beyond the attention-narrowing effects of fear and anxiety.

2.1 Encoding and Positive Affect

Positive mood induction has been shown to promote semantic processing, which is associated with deeper levels of encoding and improved long-term retention of information (Brand, et al., 2007; Bryan, Mathur, & Sullivan, 1996; Clore & Huntsinger, 2007; Clore & Storbeck, 2006; Craik, 2002; Craik & Lockhart, 1972; Ellis, Thomas, & Rodriguez, 1984; Haänze & Hesse, 1993; Kiefer, Schuch, Schenck, & Fiedler, 2007; Kiefer, et al., 2007; Lee & Sternthal, 1999; Leight & Ellis, 1981; Storbeck & Clore, 2008). The effect of positive affect on encoding stems partly from the levels of processing framework of memory (Craik & Lockhart, 1972; Craik, 2002). The levels of processing framework is one of the most robust, most frequently cited, and most influential theories in cognitive psychology, having undergone more

than 40 years of experimentation and development (Ekuni, Vaz, & Bueno, 2011; Richardson-Klavehn, Gardiner, & Ramponi, 2002). This theory posits that various levels of depth exist in the encoding and storage of information in memory. “Deep” encoding refers to the analysis of semantic meaning, inference, and implication; in contrast, “shallow” encoding refers to analysis of surface form, color, loudness, and brightness (Craik, 2002; Craik & Lockhart, 1972). Deep encoding has been repeatedly shown to enhance memory. A prototypical study involves learning a list of words and answering a question about the word from multiple categories. Ranging from shallowest to deepest, individuals may be asked if the word was spelled in italics, if the word starts with a “b” sound, and if the word was an animal. While the former two questions pertain to the look or sound of a word, the third question requires the participant to derive meaning from the word. For example, the word *bear* is in italics, starts with a “b” sound, and is an animal. When asked if this word is an animal (i.e., ascertain its semantic meaning), information is encoded more deeply and remembered better than if asked if the word was in italics or started with a “b” sound.

Depressed mood lessens elaborative encoding, cognitive effort, and semantic processing during encoding relative to neutral or positive mood (Bolte, Goschke, & Kuhl, 2003; Ellis, Thomas, & Rodriguez, 1984; Hartlage, et al., 1993; Leight & Ellis, 1981). Conversely, positive mood is associated with improved semantic processing, such as being better able to find a common word (e.g., black) combining three distantly related words (e.g., widow, board, cat) (Isen, Daubman, & Nowicki, 1987), processing related words (Haänze & Hesse, 1993), and processing distantly related un-expected words (Federmeieira, et al., 2001). Similarly, positive mood enhances semantic processing of information in studies of semantic priming (Haänze & Hesse, 1993; Storbeck & Clore, 2008). Specifically, individuals in a positive mood react more

quickly when primed with a word (e.g., NURSE) from the same semantic category as the target word (e.g., DOCTOR) than individuals in a negative mood. Neurobiologically, positive mood has been shown to increase activity in brain regions associated with semantic processing, such as the medial temporal lobe (i.e., parahippocampal, fusiform, and lingual gyri) and prefrontal cortex (i.e., left inferior prefrontal cortex, frontal midline, anterior cingulate; Erk, et al., 2003; Kiefer, et al., 2007; Nyberg, 2002; Vandenberg, et al., 1996) compared to negative mood.

Moreover, positive mood is associated with increases in relational processing, or relating incoming information to already-known information (Clore & Huntsinger, 2007). Conversely, negative mood is associated with more referential processing, which involves analyzing perceptual details of a stimulus in isolation of already-known information (Clore & Huntsinger, 2007). Individuals in a positive mood are more likely to see connections (Isen & Daubman, 1984) and focus on global rather than local aspects of what they see (Gasper & Clore, 2002).. Conversely, individuals in negative moods are less likely to use past learned information (Bless, et al., 1996; Bodenhausen, 1994; Isbell, 2004) and are more likely to process incoming information independently of currently accessible information (Storbeck & Clore, 2005). Together, these findings suggest that positive mood facilitates integration of prior learning history with currently acquired information, whereas negative mood does not.

Furthermore, positive affect can generate false memory as a function of enhanced semantic processing during encoding. Storbeck and Clore (2005) found that individuals in a positive mood were more likely to falsely remember having seen critical lures in a word list than individuals in a negative mood. For example, a list of words may include *bed*, *pillow*, *rest*, *awake*, and *dream*. By activating a semantic network of related words and concepts, individuals may later believe they saw the word *sleep* (i.e., the critical lure) even though it was not presented

in the list. By engaging in more semantic processing, individuals with more positive mood are more likely to activate the non-presented word *sleep* during encoding. At the time of retrieval, they might remember thinking about the word *sleep* but may misattribute it to being part of the actual word list (e.g., thinking they saw the word *sleep*), especially if they were in a positive mood. Storbeck and Clore (2005) were able to demonstrate that the critical time period for the false memory effect was during encoding, not during retrieval.

In sum, positive affect can enhance encoding by promoting semantic processing of information. It can also engage relational processing, which will integrate already-known information with the new incoming information. Positive affect additionally enhances the false memory effect by increasing semantic processing.

2.2 Encoding and Extinction

During extinction, individuals learn a new inhibitory CS+/No-US association that competes with the already-existing excitatory CS+/US association. Essentially, a new inhibitory meaning of the CS+ is developed during extinction. Because semantic processing involves learning the *meaning* of a stimulus, semantic processing could enhance learning the second, inhibitory meaning of the CS+ relative to shallower processing. Conversely, shallower levels of processing may lead to more focus on shape, color, form, and other features of the CS+ and less learning about the inhibitory meaning of the CS+. Deeper encoding may additionally enhance safety learning regarding the CS-.

Excitatory and inhibitory associations compete with each other to produce the net amount of conditional fear (Bouton, 1993). Conditional fear is greater when the excitatory association is relatively stronger than the inhibitory association. Spontaneous recovery – or, increases in

conditional fear proportional to the passage of time from the end of extinction to the next time the CS+ is encountered – involves a competition between excitatory and inhibitory learning. Individuals who more deeply encode extinction learning would be expected to demonstrate less spontaneous recovery because they remember the inhibitory learning more than individuals who encode the learning more shallowly, as deeper encoding is related to improved retrieval (Craik, 2002; Craik & Lockhart, 1972). Importantly, spontaneous recovery is typically measured as the fear from the end of extinction to a follow-up time period (Rescorla, 2004). Rather, given that the fear level at the end of extinction or the reduction in fear from the start to end of a given extinction period is not a reliable predictor of fear at a follow-up test that occurs after the consolidation period (Craske, et al., 2008), a more appropriate test of inhibitory learning would involve fear from the first extinction trial (or last acquisition trial) to the test trial. This would measure how much fear reduces in the long term from before to after extinction. As such, while deeper encoding of inhibitory learning may reduce spontaneous recovery, a possibly more important measure is the amount of fear reduction from before extinction to a follow-up test on a different day.

A similar effect may occur with reacquisition. During reacquisition, the excitatory association is re-experienced (i.e., re-pairings of the CS+ and US). Deeper processing during extinction may bolster the strength of the inhibitory association and thereby weaken the strength of the excitatory association during reacquisition. Indeed, we (Zbozinek & Craske, 2017) found that higher positive affect (but not negative affect) before and after extinction predicted a slower reacquisition of CS+ fear as measured by skin conductance arousal and expectancy for the aversive event but not self-report fear. Unfortunately, mood induction was not conducted in this

study, so the data are based on natural fluctuations in measurements of positive and negative affect.

Deeper encoding during extinction may also attenuate reinstatement. Though there are many theories of reinstatement, most suggest that a reinstating US increases context conditioning which then transfers to the CS+ when presented in the reinstatement context (Bouton, 2002; Dirikx, et al., 2004; Schmajuk, Larrauri, & LaBar, 2007; Westbrook, et al., 2002). Reinstatement involves delivery of the US in absence of the CS+ (Rescorla & Heth, 1975). Deeper encoding during extinction may result in a greater inhibitory learning, which may provide resistance to reinstatement. Lastly, deeper encoding during extinction may weaken context renewal. Positive mood is associated with enhanced heuristic learning (Clore & Huntsinger, 2007). This type of learning may de-emphasize the details of the context in which extinction occurred (e.g., in this specific context, the CS+ will not predict the US) and promote a more general form of inhibitory learning (e.g., the CS+ generally no longer predicts the US) that facilitates generalization of extinction learning to new contexts. Alternatively, positive mood may enhance the encoding that occurs during extinction, which may emphasize that the CS+ does not predict the US within this specific context. This would be expected to result in greater renewal of fear. We are unaware of any studies investigating the effects of increased positive affect during extinction on renewal fear, so these competing hypotheses await testing.

Positive affect enhances relational processing, or relating incoming information to already-known information. Conversely, negative affect enhances referential processing, or learning new information in isolation of already-known information (Clore & Huntsinger, 2007). Because fear acquisition precedes fear extinction, relational processing will facilitate the integration of the new incoming inhibitory association with the original excitatory association

during extinction. Integration of this type is likely to have two effects. First, it may activate excitatory and inhibitory associations at the same time, and, second, it may affect US expectancy and fear during extinction (the latter is discussed in the “Encoding and Exposure” section below). A famous postulate of Hebbian plasticity (Hebb, 1949) is that “neurons that fire together wire together.” That is, neurons that are active at the same time will develop a stronger connection to each other. Hence, by activating both excitatory and inhibitory associations during extinction, relational processing may increase the chances that activation of the excitatory association at a later time (e.g., when the CS+ is re-encountered) will also activate the inhibitory memory, thus reducing fear.

Positive mood during encoding also increases processing of semantically related concepts that were not present in the learning material itself (Storbeck & Clore, 2005). Thus, semantic processing may promote generalization of extinction learning from one CS+ to another CS+ or a generalization stimulus (GS) that was not present in the extinction trial. Moreover, because negative mood increases item-specific analyses (Clore & Huntsinger, 2007), a negative mood state during extinction might better encode physical details of the CS+ encountered during extinction. Consequently, negative mood may enhance stimulus discrimination and therefore reduce generalization of extinction learning. This same logic may apply to contexts. Positive mood may enhance semantic activation of contexts other than the extinction context, which may reduce renewal. Similarly, negative mood may enhance discrimination of the extinction context from other contexts. Together, these results suggest that positive mood will increase extinction generalization whereas negative mood will decrease extinction generalization with both different CSs and different contexts.

2.3 Encoding and Exposure

Deeper encoding and semantic processing during exposure is likely to stabilize the long-term outcomes from exposure therapy by reducing the return of fear due to spontaneous recovery, reacquisition, reinstatement, and possibly renewal. Deeper encoding may also reduce fear of safety signals in individuals with anxiety disorders by enhancing learning that safety signals do not predict aversive events. Because relational processing involves integrating new information with previously learned information, an initial effect during the early stages of exposure will be to increase expectancy for the aversive event, which should enhance inhibitory learning. After multiple exposures, relational processing will mean greater integration of new inhibitory meanings with both the already-learned excitatory meaning *and* inhibitory meanings from prior interactions with the phobic stimulus, which should lead to lower expectancy and fear. For example, individuals phobic of dogs who undergo exposure while experiencing positive affect (compared to low positive affect) should have increased expectancy that the dog will attack them, which will enhance inhibitory learning. Later exposures with high positive affect will involve the integration of this excitatory association with the newly learned inhibitory association (i.e., that the dog will not attack the individual), which will reduce expectancy and fear.

Furthermore, semantic processing is likely to increase the generalization of exposure therapy. Using the dog phobia example from above, individuals who are phobic of dogs may be afraid of various breeds of dogs, various sizes, and various objects semantically related to dogs that act as second-order CSs (e.g., bowl of dog food, pet store). Semantic processing during exposure to a golden retriever dog may activate thoughts or images of other types of dogs (e.g., German shepherd, poodle) and semantically related stimuli (e.g., pet store) so that exposure

learning generalizes to other stimuli that were in fact not encountered physically during exposure. Similar generalization effects may be observed with context renewal. For example, if dog exposure is conducted in a park, this may semantically activate the client's backyard, which may reduce fear when the dog is encountered in the client's backyard at a later time. To the degree that positive mood enhances encoding and semantic processing, positive mood should improve the long-term stability and generalization of exposure learning to both different CSs and contexts.

3.1 Rehearsal and Positive Affect

Because positive mood is associated with semantic processing, this may result in deeper rehearsal of information, which would in turn enhance long-term memory (Craik, 2002; Craik & Lockhart, 1972). Rehearsal of information entails keeping the target information in consciousness and continued attention to the stimulus. Deeper processing involves further analysis of the semantic meaning of a stimulus (i.e., Type II rehearsal), whereas shallower processing involves repetition of analyses that have already been conducted (i.e., Type I rehearsal). Type II rehearsal improves memory performance compared to Type I rehearsal. Interestingly, Type II rehearsal does not require more time than Type I, but it does require more attention (Craik & Byrd, 1982; Treisman, 1964). When attention is eventually diverted from the stimulus, the rate of information loss is slower with deeper processing than with shallower processing (Craik, 2002; Craik & Lockhart, 1972). Also, the depth of rehearsal depends upon both the usefulness of the information to the individual of continuing to process at the current level and also upon the amenability of the material for deeper processing. Similarly, merely presenting the stimulus repeatedly will not enhance memory performance (Moray, 1959;

Norman, 1969; Tulving, 1966; Turvey, 1967) since repetition without the intention to learn does not enhance learning.

Furthermore, in retrieval-induced forgetting, repeated retrieval of a subset of previously observed events can decrease memory of the non-retrieved events (Anderson, 2003; Anderson, Bjork, & Bjork, 1994, 2000), a phenomenon that is enhanced by positive mood (Bäuml & Kuhbandner, 2007). For instance, retrieval of some word pairs from various semantic categories improves recall relative to non-retrieved items (Bäuml & Kuhbandner, 2007). Typically, this retrieval is done within minutes after encoding (e.g., Smith & Hunt, 2000). Because information tends to compete with other information for memory (i.e., interference; e.g., Jonides & Nee, 2006), retrieval-induced forgetting is posited to derive from inhibition of the interfering information (i.e., non-rehearsed information) in order to maximize recall of the rehearsed information (Anderson & Spellman, 1995). The inhibition effect should be particularly evident in related items (e.g., animal-fi___ and animal-mouse) relative to non-related items (e.g., animal-fi___ and drink-lemonade), as related items cause more interference with each other (Anderson, 2003). Notably, processing information in an item-specific way (i.e., referential processing) reduces retrieval-induced forgetting (Smith & Hunt, 2000). Since negative affect enhances item-specific and referential processing whereas positive affect enhances global and relational processing (Clore & Huntsinger, 2007), positive mood during retrieval enhances retrieval-induced forgetting relative to negative mood (Bäuml & Kuhbandner, 2007). Thus, retrieval of information improves recall for the retrieved information and reduces recall of the non-retrieved information, and this effect is enhanced by positive mood.

3.2 Rehearsal and Extinction

Because Type II (i.e., deeper) rehearsal results in more learning than Type I (i.e., shallower) rehearsal (Craig, 2002; Craig & Lockhart, 1972), deeper rehearsal after extinction may enhance extinction learning. Albeit related to fear acquisition rather than extinction, Davey and Matchett (1994) found that simple mental rehearsal of the excitatory CS+/US association increased conditional fear. It is thus plausible that mental rehearsal of the inhibitory CS+/No-US relationship reduces conditional fear. Rehearsing the inhibitory CS+/No-US relationship while in a positive mood may enhance learning compared to rehearsal in a negative mood.. Furthermore, rehearsal of the inhibitory association may serve to both strengthen its memory and decrease memory of the excitatory association via retrieval-induced forgetting (Anderson, 2003; Anderson, Bjork, & Bjork, 1994, 2000).

3.3 Rehearsal and Exposure

Translation of these principles to exposure therapy highlights the value in rehearsing the non-occurrence of the aversive event (i.e., the new inhibitory learning) immediately after completion of an exposure practice (Craske et al., 2014). More specifically, rehearsal after exposure therapy should involve “analyses” or considerations that have not been conducted previously and that elaborate on the learning. For example, an individual who fears public speaking may rehearse evidence of the absence of signs of audience rejection after an exposure to public speaking. This may include rehearsing the audience’s maintained positive non-verbal cues (e.g., eye contact, nodding of heads) and absence of explicit statements of rejection throughout the speech. Rehearsal may be even further elaborated upon in accordance with inhibitory learning principles (Craske, et al., 2014), such as rehearsing the non-occurrence of the aversive event despite omission of safety signals (e.g., written notes for the speech) from the

exposure. Engaging in this form of rehearsal (often using Socratic questioning and guided discovery) may help individuals rehearse information which they were not explicitly aware of during the exposure itself. Positive affect may enhance these rehearsal effects.

In addition to rehearsing this information deeply, the act of retrieving the inhibitory memory may enhance the later recall of the exposure memory through retrieval-induced forgetting of the original excitatory memory, leading to greater stability in the long-term outcomes from exposure.

4.1 Consolidation and Positive Affect

Higher levels of arousal are associated with enhanced consolidation of memory (i.e., the post-learning process in which memories are stored into long-term memories), especially with emotionally arousing information. For example, amphetamine administration before or after learning enhances consolidation and memory (Soetens, et al., 1995). The effects of emotional arousal upon memory are attributable to activation of β -adrenergic stress hormone systems during and after an emotional experience (e.g., McGaugh, 1989, 2000). Hence, β -adrenergic receptor antagonists (propranolol hydrochloride) reduce memory for emotionally arousing material one week later but have no effect on memory for non-emotionally arousing material (Cahill, Prins, Weber, & McGaugh, 1994).

Unlike other areas of learning and memory, the valence of affect (i.e., positive or negative) does not influence consolidation of learning (Liu et al., 2008; Nielson & Powless, 2007). Because both positively and negatively arousing experiences increase levels of stress hormones (Merali, et al., 1998), it follows that both positively and negatively valenced arousal enhance consolidation.

4.2 Consolidation, Extinction, and Exposure

Because arousal (rather than affective valence) is the critical factor for enhancing consolidation of memory (Liu, et al., 2008; Nielson & Powless, 2007), positive affect is unlikely to improve consolidation of memory over and above negative affect during either extinction or exposure therapy.

5.1 Retrieval and Positive Affect

The effect of positive affect on retrieval of information is partly related to the levels of processing framework. In particular, encoding information at a deeper level will enhance long-term memory (Craik, 2002; Craik & Lockhart, 1972; Ekuni et al., 2011). Transfer-appropriate processing (Morris, Bransford, & Franks, 1977; Weldon, Roediger, & Challis, 1989) expands on the levels of processing framework to account for the effects of encoding-by-retrieval interactions on memory. Results show that semantic encoding enhances the potential for improved long-term memory, particularly when the retrieval circumstances are also semantic (Craik, 2002; Morris, Bransford, & Franks, 1977; Weldon, Roediger, & Challis, 1989).

Furthermore, memory is mood-congruent (e.g., Gaddy & Ingram, 2014), such that individuals who are depressed are more likely to recall explicit depression-congruent information than individuals who are not depressed (Watkins, Mathews, Williamson, & Fuller, 1992). Meta-analytic findings indicate mood-congruent memory for positive mood as well as depressed mood, since induced elation is associated with greater recall of positive information (Matt, Vázquez, & Campbell, 1992). Mood-congruent memory is explained by the semantic associative network model (Bower, 1981; Bower, et al., 1978). This theory states that memory is a network

of interconnected but separate nodes of information that represent knowledge, experiences, emotions, and concepts. The spread of activation from one node to another occurs automatically. In the context of mood-congruent memory, a sad mood is hypothesized to spread activation to sad concepts, knowledge, and experiences and enhance retrievability of this information. A positive mood induces a corresponding process. However, mood-congruent memory has been largely studied in the context of depression (not anxiety), and depression is more strongly associated with a negative memory bias than anxiety (Craske, et al., 2009).

5.2 Retrieval and Extinction

According to the levels of processing and transfer-appropriate processing theories (Morris, Bransford, & Franks, 1977; Weldon, Roediger, & Challis, 1989), if the meaning of the extinction-based inhibitory association is deeply encoded, then presentation of the CS+ following extinction is more likely to retrieve the inhibitory meaning. This is maximized when the individual is engaging in semantic processing at retrieval. The degree to which the inhibitory meaning is retrieved relative to the excitatory meaning may depend on how well the retrieval circumstances match those of encoding. For example, because positive affect enhances deeper, semantic encoding, retrieval could be improved when individuals are in a positive mood versus a negative mood during retrieval. Thus, positive affect during extinction and positive affect at a later time when the CS+ is re-encountered could maximize both encoding and retrieval of extinction learning. Moreover, from the mood-congruent memory model, high positive affect during extinction should result in superior retrieval of the inhibitory memory when re-encountering the CS+ with high positive affect than with low positive affect.

5.3 Retrieval and Exposure

Generally speaking, mood-congruent memories (e.g., Bower, 1981) suggest that consistently positive mood, which carries across both exposure therapy and later circumstances of re-encountering the previously feared stimulus, will enhance the retrieval of the inhibitory association relative to the more negative excitatory fear memory. Consequently, consistently positive mood should lessen the return of fear following exposure therapy. This may be difficult, however, for individuals with persistently low positive affect. For example, because depression is highly comorbid with anxiety (Watson, 2005) and because social anxiety disorder (Brown, Chorpita, & Barlow, 1998; Kashdan, 2007), generalized anxiety disorder (Prenoveau et al, 2010), and posttraumatic stress disorder (Hopper et al, 2008; Litz, Orsillo, Kaloupek, Weathers, 2000) have also been associated with low positive affect, some individuals undergoing exposure therapy may have persistently low positive affect. For these individuals, inducing a positive mood during exposure may create a mismatch between mood during exposure and mood during retrieval, with the latter less likely to be connected with high positive affect. While increasing positive affect during exposure could enhance learning mechanisms at that time (e.g., attention, encoding, rehearsal), less positive affect at retrieval could mitigate the interaction between encoding and retrieval and thus increase fear at retrieval (relative to positive mood at retrieval).

However, negative memory biases are more strongly associated with depression than with anxiety disorders (Craske, et al., 2009; MacLeod & Mathews, 1991; Mineka & Nugent, 1995). Some studies suggest poorer explicit memory of threat-related material in anxiety disorders relative to controls (Watts, Trezise, & Sharrock, 1986), whereas others show enhanced memory of threat-relevant material (Mathews & MacLeod, 2005). However, the latter is attributed to superior encoding of emotionally relevant information rather than retrieval-based

processes. Retrieval-based memory biases are much more robustly observed for depression and constitute much of the literature on mood-congruent retrieval (e.g., Watkins, et al., 1992). Depressed individuals have a bias towards information associated with loss and failure (e.g., negative self-descriptive adjectives; Derry & Kuiper, 1981) but not threat (Mineka & Nugent, 1995). Given the lack of evidence for a robust negative memory bias for threat-relevant material in anxiety disorders, the extent to which positive affect influences memory for threat-relevant material in an exposure setting is unclear. However, consistent with the evidence for negative mood to be associated with greater recall of negative information, we would predict that higher negative mood at retrieval would be associated with greater fear at retrieval.

Furthermore, based on the transfer-appropriate processing model (Morris, Bransford, & Franks, 1977; Weldon, Roediger, & Challis, 1989), retrieval of learning during exposure will be enhanced if the circumstances during exposure are similar to the circumstances at retrieval. Thus, exposures that closely imitate real-world situations in which the individual is likely to encounter their previously feared stimuli would be beneficial. Positive mood states during exposure are likely to enhance this effect, since positive affect enhances semantic processing. Being in a more positive mood both during exposures and when the feared stimulus is re-encountered should reduce fear and expectancy for an aversive event.

6.1 Stimulus Valence and Positive Affect

It is widely accepted that affective states interact with cognitive processing (Ashby & Isen, 1999; Forgas, 1995; Nadler, Rabi & Minda, 2010). Most pertinent is the effect of positive affect on stimulus valence. As stated before, the “affect-as-information” model states that affect is used as information to make evaluative judgments (Clore & Huntsinger, 2007). Positive affect

increases positive valence of stimuli (i.e., Erez, et al., 2002; Isen & Shalker, 1982; Yeung & Wyer, 2004; Zbozinek, Holmes, & Craske, 2015). State positive affect can also increase momentary appraisals of how happy individuals are with their lives in general (Schwarz & Clore, 1983).

6.2 Stimulus Valence and Extinction

Conditional responding to the CS+ includes increased arousal as well as negative valence towards the CS+. The latter tends to be more resistant to extinction than the former (Hermans, et al., 2002). Post-extinction CS+ valence is a known predictor of return of fear via reinstatement (Dirikx, et al. 2004; Dirikx., et al., 2007; Hermans, et al., 2005; Zbozinek, Prenoveau, et al., 2015), which suggests that efforts to increase CS+ valence could reduce reinstatement. Indeed, we (Zbozinek, Holmes, & Craske, 2015) found that positive mood induction before extinction increased CS+ valence from before to after extinction and decreased reinstatement fear one week later as measured by self-report and startle reflex. Conceivably, positive mood induction reduced reinstatement fear by increasing CS+ valence as well as other aspects of learning and memory (e.g., enhanced encoding of the inhibitory association). Moreover, according to the affect-as-information (Clore & Huntsinger, 2007) and affect-as-cognitive-feedback models (Huntsinger, Isbell, & Clore, 2014), positive affect during extinction would reinforce the thoughts and mental processes associated with inhibitory learning. In other words, positive affect would more strongly validate the appraisal that the CS+ does not predict the US than negative affect.

6.3 Stimulus Valence and Exposure

Positive mood during exposure could increase positive evaluations of the feared stimulus (e.g., how much the feared object is liked). For example, an individual who retains positive mood while undergoing exposure therapy for social anxiety might be more prone to eventually like or enjoy social situations than someone whose mood is consistently negative. This has relevance especially for reinstatement of fear. Using a clinical example, being verbally insulted (US) for accidentally bumping into someone while walking down a sidewalk may be less likely to lead to a return of fear of starting conversations with people (CS+) if previous exposures were conducted in a positive mood. Additionally, more positive evaluations of the previously feared stimulus may increase approach behavior towards it. Using the same clinical example above, an individual who enjoys starting conversations might be more likely to voluntarily start conversations in the future than someone who dislikes starting conversations. Such continuing approach should contribute to the long-term benefits of exposure therapy.

7.1 Summary of Positive Affect and General Learning

Table 1 summarizes the effects of positive affect on learning, memory, and cognition, as well as its application to extinction/exposure. Positive affect can affect attention and has beneficial effects for encoding, rehearsal, retrieval, and stimulus evaluation over negative affect, but both positive and negative affect enhance consolidation via increased arousal. First, two theories posit specific pathways through which positive affect influences attention. According to the motivational intensity model, highly goal-directed emotions narrow attention, whereas non-goal-directed emotions broaden attention. Positive affect that is goal-directed (such as desire and enthusiasm) narrows attention, whereas non-goal-directed positive affect (such as amusement and contentment) broadens attention. Alternatively, the affect-as-cognitive-feedback model states

that positive affect may maintain the current scope of attention (whether it is narrow or broad) and negative affect may change it. Second, positive affect may enhance encoding of information by encouraging semantic processing, which in turn improves long-term memory. Positive affect also increases relational processing, meaning that incoming information is integrated with previously learned information (as opposed to referential processing, which processes incoming information independently of previously learned information). Positive affect can also increase false memory for items that are semantically related but not actually learned. Third, positive affect may enhance rehearsal through semantic processing. Positive affect can also result in retrieval-induced forgetting, which enhances recall of rehearsed items and decreases recall of non-rehearsed items. Fourth, positive affect does not influence consolidation of learning over and above the effects of negative affect. Rather, arousal is the critical factor that affects consolidation, with higher arousal increasing consolidation. Fifth, positive affect may enhance retrieval of information when retrieval circumstances are similar to those of encoding. Positive affect at the time of retrieval may also result in mood-congruent recall of positive information. Lastly, positive affect increases positive valence of stimuli.

Table 1.

Summary of the Effects of Positive Affect on Learning, Memory, and Cognition

Cognitive Process	Relevance for General Learning	Relevance for Extinction/Exposure	Example Citations
Attention	Motivational intensity model – highly goal-directed emotions (positive or negative) narrow attention.	Increasing goal-directed emotions can narrow attention on the CS+ and enhance inhibitory learning.	Gable & Harmon-Jones, 2008
	Affect-as-cognitive-feedback model – positive emotion maintains ongoing mental processes (e.g., breadth of attention), whereas negative affect changes them. Positive affect will maintain ongoing narrow attention.	Prior to engaging in extinction/exposure, fear is heightened and attention is narrowed. Increasing positive affect would maintain ongoing narrow attention during extinction/exposure.	Huntsinger, Isbell, & Clore, 2014
Encoding	Levels of processing theory – positive affect enhances semantic processing, which may improve memory.	Increasing positive affect during extinction/exposure may enhance inhibitory learning and reduce long-term fear. May also reduce CS- fear in anxious individuals.	Brand, et al., 2007; Craik, 2002; Craik & Lockhart, 1972; Lee & Sternthal, 1999
	Positive affect enhances relational processing (i.e., integrating incoming information with already-known information). Negative affect enhances referential processing (i.e., processing incoming information in isolation of already-known information).	Increasing positive affect during extinction or exposure may integrate already-known information (excitatory association) with incoming information (inhibitory association). This may increase violation of US expectancies during extinction, increase activation of the inhibitory association later when the excitatory association is activated, and reduce long-term US expectancy and fear.	Clore & Huntsinger, 2007
	False memory effects – by activating semantic processing, positive affect can enhance false memory of semantically related concepts that were not present during encoding.	May promote generalization of extinction learning to semantically related CSs or contexts that were not physically present in the exposure itself.	Storbeck & Clore, 2005
Rehearsal	Levels of processing theory – positive affect enhances semantic processing, which may enhance rehearsal of information and memory.	Positive affect may enhance the inhibitory learning that results from rehearsal of the extinction or exposure trial.	Craik, 2002; Craik & Lockhart, 1972; Lee & Sternthal, 1999
	Retrieval-induced forgetting – rehearsal of a subset of information will enhance memory for that subset while simultaneously reducing memory for the non-rehearsed subset. This effect is enhanced by positive affect and reduced by negative affect.	Positive affect may improve memory of the rehearsed inhibitory association while also reducing memory of the non-rehearsed excitatory association.	Bäuml & Kuhbandner, 2007
Consolidation	Higher arousal increases consolidation of learning, but emotional valence does not affect consolidation. Thus, positive affect does not affect consolidation over and above the effects of negative affect.	Higher levels of arousal after extinction/exposure may increase consolidation of inhibitory learning.	Liu et al., 2008; Nielson & Powless, 2007
Retrieval	Transfer-appropriate processing – retrieval is optimized when encoding circumstances match those of retrieval. Having semantic encoding/retrieval or positive mood at both encoding and retrieval may maximize recall.	Positive affect at both encoding and retrieval may improve recall of the inhibitory association. Also, the more circumstances between encoding and retrieval are similar, the better the recall, and thus the greater reduction of fear.	Craik, 2002; Morris, Bransford, & Franks, 1977
	Mood-congruent memory – positive affect at retrieval may enhance memory of positive information.	Positive affect at retrieval may increase recall of positive memories, such as the inhibitory association.	Matt, Vázquez, & Campbell, 1992
Stimulus Valence	Affect-as-information model – positive affect may increase stimulus valence (i.e., "liking" of the stimulus), whereas negative affect may decrease stimulus valence.	Positive affect during extinction may increase CS+ valence, which can reduce reinstatement fear and promote willingness to conduct exposures and approach the CS+.	Clore & Huntsinger, 2007

7.2 Summary of Positive Affect, Extinction, and Exposure

Positive affect during extinction can facilitate extinction learning by influencing attention, encoding, rehearsal, retrieval, and CS+ valence. First, because attention towards the CS+ is required to learn new information about the CS+, positive affect with high motivation (e.g., desire, enthusiasm) and narrowed attention on the CS+ should enhance learning to the CS+. Using either the Rescorla and Wagner (1972) model or the updated Pearce and Mackintosh (2010) model, positive affect with narrowed attention on the CS+ during extinction could enhance extinction learning.

Second, by enhancing semantic processing of the inhibitory CS+/No-US association, positive affect may lead to greater retention of this information. This may mitigate all four forms of return of fear: spontaneous recovery, renewal, reacquisition, and reinstatement. Relational processing during extinction may also activate the excitatory CS+/US association, which would likely increase US expectancy during extinction and thereby enhance inhibitory learning. Relational processing could also facilitate activation of the inhibitory association in the future alongside the excitatory association, thus reducing return of fear. In contrast, a negative mood during extinction encourages referential processing, which would enhance learning of the specific CS+ during extinction in isolation of prior knowledge (i.e., the excitatory association). Semantic processing could also reduce fear of safety signals (i.e., CS-), which tends to be elevated in individuals with anxiety disorders. Furthermore, the activation of semantic processes that results from positive mood could lead to generalization of extinction learning, as similar stimuli to the CS+ would be brought to memory during extinction or similar contexts to the extinction context. Conversely, negative mood may enhance discrimination of the CS+ from other CSs or the extinction context from other contexts.

Third, positive affect enhances semantic processing, which may promote rehearsal of the semantic meaning of a stimulus. The rehearsal after exposure therapy should involve “analyses” or considerations that have not been conducted previously and should elaborate on the inhibitory learning. Such rehearsal should sustain long-term extinction learning/exposure therapy. Also, retrieving the inhibitory association after exposure may enhance memory of the inhibitory association while simultaneously reducing memory of the excitatory association. Fourth, greater positive mood at retrieval can improve retrieval of extinction learning/exposure therapy. Lastly, positive affect can overall increase positive valence of the feared stimulus. This has implications for reducing reinstatement fear (Zbozinek, Holmes, & Craske, 2015), may increase willingness to spontaneously engage in exposures in the future, and can validate inhibitory thoughts during an exposure.

Introduction to Studies 1, 2, and 3

The three experimental studies in this dissertation are three empirical evaluations of the theory that positive affect during extinction will enhance extinction learning and reduce long-term fear. Study 1 examines the degree to which positive and negative affect at various time points predict reacquisition of fear. Unfortunately, the mood induction failed in this study, so our results do not contain the effects of experimental manipulation of mood during extinction on reacquisition fear. Study 2 builds upon Study 1 and employs a successful mood induction examining reacquisition, as well as spontaneous recovery and long-term extinction learning (i.e., fear from the end of acquisition to test). Study 3 similarly employs a successful mood induction during extinction of generalization stimuli. The study investigates the effects of mood induction on extinction learning to the generalization stimuli present during extinction, the unextinguished CS+, and a novel generalization stimulus.

Study 1: Positive Affect Predicts Less Reacquisition of Fear: Relevance for Long-Term
Outcomes of Exposure Therapy

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Abstract

Much emphasis in fear conditioning research is placed on understanding extinction learning, partly because of its application in treating anxiety disorders. Return of fear after extinction is a problem affecting long-term maintenance of treatment gains. The present study evaluated whether positive affect (PA) is associated with lower rates of reacquisition, or, an increase in fear following re-pairings of the conditional stimulus (CS+) and unconditional stimulus (US; e.g. electric shock) after extinction. Results showed that higher PA before and after extinction was associated with less CS+ fear during reacquisition as measured by skin conductance arousal and US expectancy. Conversely, negative affect was not associated with reacquisition of fear using any measure. These results provide implications for reducing reacquisition with exposure therapy for anxiety disorders.

Introduction

Exposure is well-established as an effective therapeutic strategy for anxiety disorders (Hofmann & Smits, 2008; In-Albon & Schneider, 2007). However, a number of individuals experience a return of fear following exposure therapy (Craske & Mystkowski, 2006; Rachman, 1989). Greater understanding of the mechanisms responsible for return of fear may inform interventions that enhance long-term treatment gains. Processes of extinction learning are considered to be key mechanisms of exposure therapy (Hermans, Craske, Mineka, & Lovibond, 2006). In a prior study (Zbozinek, Holmes, & Craske, 2015), we demonstrated that higher levels of positive affect (PA) prior to extinction reduced reinstatement of fear, which is one pathway to return of fear. In the present study, we evaluated whether higher levels of PA prior to extinction predict less fear during reacquisition, which is another pathway to the return of fear.

Within inhibitory learning models, the original conditional stimulus (CS+)/unconditional stimulus (US) association learned during acquisition of fear is not erased during extinction, but rather is left intact while a new, secondary CS+/NoUS inhibitory association develops (Bouton, 1993). This means that, after acquisition and extinction, individuals possess two memories of the CS+: one in which it predicts an aversive event and a separate memory in which it predicts no aversive event. Because the original excitatory meaning (CS+/US) remains intact after extinction, it can be retrieved following extinction. In the context of exposure therapy, retrieval of the excitatory CS +/US association after treatment translates to a return of fear (Vervliet, Hermans, & Craske, 2013).

Several phenomena demonstrate retention of the original excitatory CS+/US association following extinction training. These include renewal, or increased conditional fear resulting from a change in context between extinction and test (Bouton & King, 1983). Contexts may be

exteroceptive (e.g. a room, place, environment, or other external background stimuli; Bouton, 1993) or interoceptive, such as drug state (Bouton, Kenney, & Rosengard, 1990; Overton, 1985). The clinical translation of context renewal is exemplified by return of fear in a public speaking situation (e.g. a wedding) that differs from the public speaking practiced in exposure therapy (e.g. clinic office). Second, unsignalled US presentations (without the presence of the CS+) after extinction can lead to a reinstatement of fear (Rescorla & Heth, 1975). For example, an individual who is treated for specific phobia of snakes (CS+) after being bitten (US) by a snake may experience reinstatement of fear of snakes after being bitten by a dog. Reinstatement has been long established in animal studies and more recently in human conditioning studies (Dirikx, Hermans, Vansteenwegen, Baeyens, & Eelen, 2004, 2007; Hermans et al., 2005; LaBar & Phelps, 2005; Norrholm et al., 2006; Van Damme, Crombez, Hermans, Koster, & Eccleston, 2006; Zbozinek, Holmes, et al., 2015; Zbozinek, Prenoveau, Liao, Hermans, & Craske, 2015).

Spontaneous recovery (Rescorla, 2004) is observed clinically as an increase in fear with the passage of time since the end of exposure therapy and the next time the feared stimulus is encountered. For example, an individual who completes treatment for phobia of public speaking will likely have greater fear when giving a speech months after treatment compared to giving a speech within days of the last exposure session. In rodent samples, Quirk (2002) demonstrated that conditional fear makes a full spontaneous recovery approximately 10–14 days after extinction training. The fourth demonstration of CS +/US retention is rapid reacquisition, in which the CS + and US are re-paired following extinction (Kehoe & Macrae, 1997; Napier, Macrae, & Kehoe, 1992; Rescorla, 2001). Clinically, an individual who undergoes therapy for a phobia of public speaking (CS+) may experience rapid reacquisition if ridiculed or ignored (US) by an audience after completion of exposure therapy.

In the current study, higher PA is hypothesised to be associated with less reacquisition. PA enhances processes such as encoding (Clore & Huntsinger, 2007; Craik, 2002; Craik & Lockhart, 1972; Ellis, Thomas, & Rodriguez, 1984; Isen, Daubman, & Nowicki, 1987; Kiefer, Schuch, Schenck, & Fiedler, 2007; Storbeck & Clore, 2008), rehearsal (Craik, 2002; Craik & Lockhart, 1972; Ellis et al., 1984; Isen et al., 1987), and retrieval (Craik, 2002; Craik & Lockhart, 1972; Gaddy & Ingram, 2014; Morris, Bransford, & Franks, 1977) that are likely to optimise extinction learning. PA could enhance encoding, rehearsal, and retrieval through the levels of processing framework by engaging in deeper processing (Craik, 2002; Craik & Lockhart, 1972). “Deep” encoding refers to the analysis of meaning, inference, and implication, whereas “shallow” encoding refers to analysis of surface form, colour, loudness, and brightness (Craik, 2002; Craik & Lockhart, 1972). Also, greater use of learned rules and past knowledge occurs at deeper levels, which allows information to be handled more efficiently and more information to be retained (Craik, 2002; Craik & Lockhart, 1972). Deeper levels of processing during extinction could enhance long-term extinction memories, which could reduce return of fear. Because PA is associated with deeper, semantic processing, we would expect PA to be associated with improved encoding, rehearsal, and long-term extinction memory.

High PA is also associated with increases in relational processing, or relating incoming information to already-known information. Conversely, high negative affect (NA) is associated with referential processing, which includes analysing perceptual details of a stimulus (Clore & Huntsinger, 2007). Consequently, higher PA during extinction may facilitate integration of extinction trials (i.e. incoming information) with previous acquisition trials (i.e. already-known information). By enhancing activation of the inhibitory memory of extinction in combination

with the excitatory memory of fear acquisition during rapid reacquisition trials, higher PA may be associated with lower levels of reacquisition.

In sum, higher levels of PA during extinction may enhance long-term extinction learning and reduce return of fear. We hypothesised that higher levels of PA before extinction would be associated with less reacquisition than lower levels of PA before extinction. To evaluate specificity to PA, we evaluated NA as a predictor of reacquisition. To evaluate specificity to before extinction, we evaluated PA and NA at several other time points (i.e. before acquisition, after extinction, before reacquisition), as well as trait PA and NA. To evaluate specificity to reacquisition, we evaluated PA and NA as predictors of other fear conditioning phases (i.e. acquisition, extinction, and extinction test). We also analysed the fear conditioning phases to determine whether fear conditioning followed expected trajectories; we examined whether there was differential acquisition of fear, extinction, spontaneous recovery, reacquisition, and whether reacquisition was more rapid than initial acquisition (i.e. “rapid” reacquisition).

Methods

Participants

Participants (N = 62) were students from the University of California, Los Angeles, who participated for course credit. Seven participants dropped out partway through the study, leaving 55 participants who completed the study. Participants were 67% female; mean age 21.58 (SD = 4.92) years; and 3.33% AfricanAmerican, 48.33% Asian or Asian-American, 30% Caucasian, 13.33% Hispanic/Latino, and 5% Caucasian and Hispanic/Latino. This study was approved by

the University of California, Los Angeles Institutional Review Board, and all participants provided informed consent prior to commencing the study.

Design

Participants underwent habituation, acquisition, and extinction on Day 1. One week later (i.e. Day 8), participants engaged in an extinction test phase, followed by reacquisition. CS (CS+, CS–) and time (CS trials 1, 2, etc.) were within-subject factors. Our primary independent variable was PA measured prior to extinction as an index of level of PA during extinction. We included PA measured as a trait, before acquisition, after extinction, and prior to reacquisition, as well as NA at the same time points to evaluate specificity of the effects of PA prior to extinction. We also evaluated PA and NA as predictors of other fear conditioning phases (i.e. acquisition, extinction, and extinction test) to investigate specificity to reacquisition. Lastly, we analysed the fear conditioning phases (i.e. acquisition, extinction, extinction test, reacquisition) to determine if expected learning occurred. Dependent variables included skin conductance response (SCR), US expectancy, and self-report fear.

Materials and Apparatus

CS/US

The Pavlovian conditioning procedure was programmed using E-Prime 2 Professional Version 2.0.10.353. The CS+ and CS– were images of a Caucasian male and an Asian female with neutral facial expressions (counterbalanced between participants). Facial images were

chosen because human faces as CSs may be evolutionarily prepared and result in better conditioning than non-evolutionarily prepared CSs (e.g. lights, tones) (Lissek et al., 2005; Öhman & Mineka, 2001). The CSs were displayed on a 21-in. computer monitor for 8 s located 3 ft. from the participants at eye level. To maximise CS salience, the CSs covered the entire computer screen when displayed. The CSs were pseudo-randomised with no more than two consecutive presentations of the same CS in a given phase. Inter-trial intervals (ITIs) were randomised to either 25 or 35 s and involved a white screen with a small black fixation cross in the centre. The electric shock US was delivered to the dominant arm bicep using the STMEPM, two LEAD110A (BIOPAC, Inc.), and two Telectrode T716 Ag/AgCl electrodes. The CS+/US reinforcement rate during acquisition and reacquisition was 100%; participants received eight shocks during acquisition and four shocks during reacquisition. The shock consisted of 10 consecutive pulses 0.05 s in duration, totaling 0.5 s. During the acquisition and reacquisition phases, the shock US began 7.5 s after every CS+ onset and coterminated with the CS+. The intensity of the US was determined using a work-up procedure (see section “Procedures”).

Physiological Measures

BIOPAC MP150 hardware unit and AcqKnowledge version 4.2 software (BIOPAC Systems, Inc.) were used to acquire all physiological data.

SCR: SCRs were recorded as a measure of arousal from two EL507 11 mm diameter Ag/AgCl electrodes placed on the distal phalanx of the index and middle fingers of the non-dominant hand (Bradley, Cuthbert, & Lang, 1990). Using a GSR100C amplifier and two LEAD110A, SCR data were sampled at a rate of 31.25 Hz and filtered using a finite impulse response (FIR) low pass filter with a frequency cutoff fixed at 2 Hz. SCR was calculated as a difference score between the maximum skin conductance value 1–6 s after CS onset minus the

mean skin conductance value of the 2 s prior to CS onset. SCR was range-corrected by dividing by the largest SCR per participant across both days. SCRs that were greater than zero were square root transformed to normalise the data (Zbozinek, Holmes, et al., 2015). SCRs less than or equal to zero were coded as zero.

Self-Report Measures

US expectancy: To test explicit associative learning, participants were instructed to rate “how certain you are that you will receive muscle stimulation [i.e. shock] in the next few moments” using a sliding dial (BIOPAC model TSD115). Participants received 3-s prompts at the beginning of each ITI and CS reminding them to use the expectancy dial. The values ranged from 0 = “Certain no muscle stimulation”, 4.5 = “Uncertain”, and 9 = “Certain muscle stimulation”. US expectancy was calculated as the mean rating 9.5–10 s after ITI onset and 4.5–5 s after CS+ or CS– onset).

Self-report fear: Participants rated “how fearful you are of this image” using a 1–7 scale, where 1 = “Not at all fearful of” and 7 = “Very fearful of”. “This image” refers a small image of the CS+ or CS– in the top-left corner of the computer screen. Fear was measured retrospectively after each fear conditioning phase.

Positive and Negative Affect Schedule (PANAS; Watson & Clark, 1999; Watson, Clark, & Tellegen, 1988): Participants completed the PANAS before acquisition, before and after extinction, and prior to extinction test to measure state PA and NA: “right now (that is, in the present moment)”. The trait PANAS was also completed to measure trait PA and NA: “in general, that is, on the average”. Cronbach’s α from Watson et al. (1988) was .89 and .85, respectively, and the correlation between PA and NA was $-.15$. In the present study, Cronbach’s

α was .94 for PA and .81 for NA. Correlations between all measures of PA ranged from .513 to .786 ($ps < .001$), correlations between all measures of NA ranged from .343 to .678 ($ps < .01$), and correlations between all measures of PA and NA were not significant ($ps > .092$).

Procedures

The experiment consisted of two assessments one week apart (i.e. Day 1 and Day 8). On Day 1, participants provided informed consent, and physiological equipment was attached. Participants then engaged in the shock workup procedure. Shocks started at a low intensity and increased to the level a participant considered “uncomfortable but not painful” ($M = 6.37$, $SD = 0.74$) using a 0–10 discomfort scale (0 = “Not at all”, 5 = “Moderately”, and 10 = “Very”). Participants were then trained to use the US expectancy dial. Next, participants underwent the primary experimental phases: habituation (2 CS+ and 2 CS–), acquisition (8 CS+/US and 8 CS–), and extinction (8 CS+ and 8 CS–; see Table 1 for details). On Day 8, physiological equipment was attached, participants were reminded how to use the US expectancy dial and underwent an extinction test phase (2 CS+ and 2 CS –) and reacquisition (4 CS+/US, 4 CS–).

Data Analysis

Commonly, repeated measures ANOVAs are conducted when analysing fear conditioning studies (Balooch, Neumann, & Boschen, 2012). Though this is a valid approach, multilevel modelling (Bryk & Raudenbush, 1992) offers advantages over repeated measures ANOVAs that improve the validity of the results (Kristjansson, Kircher, & Webb, 2007). While ANOVAs derive group-level variance and consider all individual-level variance as error,

multilevel modelling derives both individual-level and group-level variance. It is important to note that “individual-level” and “group-level” are relative terms in multilevel modelling. They can refer to individuals within groups, and they can also refer to repeated measures within individuals. The present study employs the latter. This partitioning of variance allows for a more accurate assessment of the phenomena under investigation and is particularly beneficial to psychophysiological experiments, as individuals vary in their physiological responses (Marwitz & Stemmler, 1998). Multilevel models also better accommodate missing data, unbalanced designs, and unequal spacing of measurement occasions (Kristjansson et al., 2007).

We thus analysed the fear conditioning phases (i.e. acquisition, extinction, extinction test, reacquisition) using growth curve models with multilevel modelling (Bryk & Raudenbush, 1992), which has been used in prior fear conditioning studies (Gazendam et al., 2015; Pineles, Vogt, & Orr, 2009). Growth curve modelling is suitable for analysing intercepts and slopes across repeated measures of fear within individuals. The intercept refers to the first time point in a series of repeated measures. The linear slope refers to the change in values across repeated measures, and the quadratic slope refers to the change in linear slope across repeated measures (i.e. acceleration/deceleration of linear slope). Using fear acquisition as an example, the intercept is the first measure point during acquisition, the linear slope is the change in fear across the repeated measures during acquisition, and the quadratic slope is the change in linear slope across the repeated measures. A higher intercept means a higher starting point of fear at the beginning of acquisition. A higher linear slope means a greater increase in fear across repeated measures, and a more negative quadratic slope means a quicker deceleration in slope (i.e. the linear slope decreases over repeated measures). All CS+ and CS– presentations within a given phase were used to calculate the slope across trials for SCR, US expectancy, and self-report fear. We also

analysed the rate of change during the first four trials of acquisition and all four trials of reacquisition to examine whether reacquisition occurred at a faster rate than acquisition (i.e. “rapid” reacquisition).

For our main hypothesis for reacquisition, we conducted growth curve models with multilevel modelling to analyse the effect of PA and NA on the intercept and slope of reacquisition for SCR, US expectancy, and self-report fear. To evaluate the specificity of effects, we used PA at each occasion (preacquisition, pre-extinction, post-extinction, pre-reacquisition, as well as trait PA) as predictors. The measures of PA were highly positively correlated ($r_s = .513$ to $.786$, $p_s < .001$). Given that multicollinearity reduces the validity of the individual predictors in a model, we chose to evaluate PA at each occasion in separate analyses. We also included NA in the models using the corresponding time points to evaluate specificity of the effects to PA (e.g. when analysing pre-extinction PA, pre-extinction NA was included in the model). We evaluated PA and NA as predictors of the intercept and slope during other fear conditioning phases (i.e. acquisition, extinction, and extinction test) to investigate the specificity of effects to reacquisition. For these analyses, we only used time points of PA and NA that were acquired before a given fear conditioning phase (e.g. when analysing acquisition, we used pre-acquisition and trait PA and NA as predictors). We also conducted t-test comparisons between the slopes for the various time points and trait measures of PA and NA within each fear conditioning phase to examine whether specific time points or trait PA and NA predict fear better than others. These comparisons were conducted between (a) significant effects involving PA or NA and (b) significant effects versus non-significant effects within the same measure of fear.

In all of the growth curve models, repeated measures (level 1) were nested within participants (level 2). CS type (CS+, CS-) was a level 1 variable. CS+ was coded as 1, and CS- was coded as 0. Thus, positive coefficients associated with CS type indicate a higher slope for the CS+ (i.e. more fear). For analyses comparing the slopes of acquisition and reacquisition, CS trials (trials 1–4), CS type (CS+, CS-), and phase (acquisition, reacquisition) were all level 1 variables. For the PA and NA analyses, PA and NA were treated as level 2 variables predicting the intercept (e.g. first CS trial of reacquisition) and slope (e.g. from first through the last CS trial of reacquisition). For all analyses except self-report fear and extinction test (which had only two time points), we plotted both a linear and quadratic slope. If the quadratic slope was not significant, we removed it from the model. Slopes and intercepts were allowed to vary randomly if they significantly varied between individuals. The multilevel growth curve models were analysed using HLM7. Preliminary analyses regarding fear to the image used as the CS+ and CS- were conducted using one-way ANOVAs with SPSS 22.0.

Results

Preliminary Results

Using one-way ANOVAs, CS Image (male CS, female CS) did not significantly predict any dependent measures ($p > .09$). Thus, CS Image was not covaried in subsequent analyses.

Acquisition

See Figure 1(a)–(c) for all fear conditioning data. In sum, there was significant differential acquisition for all measures of fear (i.e. greater increase in fear to the CS+ than CS-).

For SCR, the intercept ($t(52) = 6.248$, $b = 0.179$, $SE = 0.029$, $p < .001$) and linear slope ($t(52) = 3.587$, $b = 0.062$, $SE = 0.017$, $p < .001$) were significantly greater than zero, and the quadratic slope was significantly less than zero ($t(52) = -2.656$, $b = -0.006$, $SE = 0.002$, $p = .010$). There was a significant interaction between CS type and the linear slope with a greater increase in fear across trials for the CS+ than CS- ($t(52) = 3.729$, $b = 0.077$, $SE = 0.021$, $p < .001$). There was also a significant interaction between CS type and the quadratic slope with a stronger deceleration for the CS+ than CS- ($t(52) = -2.250$, $b = -0.006$, $SE = 0.003$, $p = .029$).

For US expectancy, the intercept ($t(54) = 10.005$, $b = 3.961$, $SE = 0.396$, $p < .001$) and linear slope ($t(54) = 6.609$, $b = 1.518$, $SE = 0.230$, $p < .001$) were significantly greater than zero, and the quadratic slope was significantly less than zero ($t(54) = -5.129$, $b = -0.145$, $SE = 0.028$, $p < .001$). There was a significant interaction between CS type and the linear slope with a greater increase in fear across trials for the CS+ than CS- ($t(54) = 7.631$, $b = 2.388$, $SE = 0.313$, $p < .001$). There was also a significant interaction between CS type and the quadratic slope with a stronger deceleration for the CS+ than CS- ($t(54) = -5.356$, $b = -0.199$, $SE = 0.037$, $p < .001$).

For self-report fear, the intercept ($t(57) = 15.069$, $b = 3.483$, $SE = 0.231$, $p < .001$) and linear slope ($t(57) = 4.979$, $b = 1.207$, $SE = 0.242$, $p < .001$) were significantly greater than zero. There was a significant interaction between CS type and the linear slope with a greater increase in fear across trials for the CS+ than CS- ($t(57) = 7.729$, $b = 2.466$, $SE = 0.319$, $p < .001$).

Neither pre-acquisition nor trait PA and NA ($ps > .201$) significantly predicted the intercept or slope of fear across acquisition trials.

Extinction

In sum, there was significant differential extinction for all measures of fear (i.e. greater decrease in fear to the CS+ than the CS-).

For SCR, the quadratic slope was not significantly different from zero ($t(738) = 1.388$, $b = 0.002$, $SE = 0.002$, $p = .166$), so it was dropped from the model. In the linear model, the intercept was significantly greater than zero ($t(52) = 7.578$, $b = 0.205$, $SE = 0.027$, $p < .001$), and the linear slope was significantly less than zero ($t(740) = -3.946$, $b = -0.016$, $SE = 0.004$, $p < .001$). There was a significant interaction between CS type and the linear slope with a greater decrease in fear across trials for the CS+ than CS- ($t(740) = -2.430$, $b = -0.012$, $SE = 0.005$, $p = .015$).

For US expectancy, the intercept ($t(54) = 20.227$, $b = 7.076$, $SE = 0.350$, $p < .001$) and quadratic slope ($t(54) = 6.734$, $b = 0.170$, $SE = 0.025$, $p < .001$) were significantly greater than zero, and the linear slope ($t(54) = -9.100$, $b = -1.937$, $SE = 0.213$, $p < .001$) was significantly less than zero. There was a significant interaction between CS type and the linear slope with a greater decrease in fear across trials for the CS+ than CS- ($t(54) = -5.962$, $b = -1.094$, $SE = 0.184$, $p < .001$). There was also a significant interaction between CS type and the quadratic slope with a stronger acceleration for the CS+ than CS- ($t(54) = 4.341$, $b = 0.105$, $SE = 0.024$, $p < .001$).

For self-report fear, the intercept ($t(57) = 21.159$, $b = 4.690$, $SE = 0.222$, $p < .001$) was significantly greater than zero, and the linear slope ($t(57) = -9.602$, $b = -1.983$, $SE = 0.206$, $p < .001$) was significantly less than zero. There was a significant interaction between CS type and the linear slope with a greater decrease in fear across trials for the CS+ than CS- ($t(57) = -7.518$, $b = -1.621$, $SE = 0.216$, $p < .001$).

Higher trait PA significantly predicted a lower linear slope across extinction trials ($t(55) = -2.030$, $b = -0.471$, $SE = 0.232$, $p = .047$) as measured by self-report fear. All other measures of pre-acquisition, pre-extinction, and trait PA and NA ($ps > .060$) did not significantly predict the intercept or slope of fear across extinction trials. T-test comparisons of linear slope for self-report fear showed that the slope of trait PA was significantly lower than the slope of pre-acquisition PA ($t(55) = -2.009$, $p = .050$); however, the slope of trait PA was not significantly different from the slope of pre-extinction PA ($t(55) = -0.646$, $p = .521$).

Extinction Test (One Week Later)

In sum, there was significant differential spontaneous recovery (i.e. greater increase in fear to the CS+ than the CS- from end of extinction to extinction test) for SCR and US expectancy but a non-differential increase in self-report fear.

For SCR, the intercept ($t(53) = 3.216$, $b = 0.107$, $SE = 0.033$, $p = .002$) and linear slope ($t(153) = 7.029$, $b = 0.261$, $SE = 0.037$, $p < .001$) were significantly greater than zero. There was a significant interaction between CS type and the linear slope with a greater increase in fear across trials for the CS+ than CS- ($t(153) = 2.048$, $b = 0.107$, $SE = 0.052$, $p = .042$).

For US expectancy, the intercept ($t(55) = 4.907$, $b = 1.567$, $SE = 0.319$, $p < .001$) and linear slope were significantly greater than zero ($t(55) = 9.071$, $b = 4.507$, $SE = 0.497$, $p < .001$). There was a significant interaction between CS type and the linear slope with a greater increase in fear across trials for the CS+ than CS- ($t(55) = 4.351$, $b = 2.252$, $SE = 0.518$, $p < .001$).

For self-report fear, the intercept ($t(57) = 10.585$, $b = 3.362$, $SE = 0.318$, $p < .001$) and linear slope ($t(57) = 2.834$, $b = 1.138$, $SE = 0.402$, $p = .006$) were significantly greater than zero.

There was also significantly greater fear for the CS+ than CS- ($t(57) = 4.036$, $b = 0.655$, $SE = 0.162$, $p < .001$). However, there was no significant interaction between CS type and the linear slope ($t(57) = 1.445$, $b = 0.310$, $SE = 0.215$, $p = .154$).

Higher pre-acquisition NA significantly predicted a higher slope for self-report fear ($t(55) = 2.241$, $b = 2.100$, $SE = 0.937$, $p = .029$). There was also a significant interaction between CS type and slope with pre-acquisition NA predicted a greater slope for the CS+ than CS- ($t(55) = 2.061$, $b = 1.035$, $SE = 0.502$, $p = .044$). Furthermore, higher post-extinction NA significantly predicted a higher intercept (i.e. higher fear after extinction) ($t(55) = 2.100$, $b = 2.040$, $SE = 0.972$, $p = .040$). Similarly, higher trait PA significantly predicted a lower intercept (i.e. lower fear after extinction) ($t(55) = -2.172$, $b = -0.777$, $SE = 0.358$, $p = .034$). All other measures of pre-acquisition, pre-extinction, post-extinction, preacquisition, and trait PA and NA ($ps > .089$) did not significantly predict the intercept or slope of fear for extinction test. T-test comparisons of linear slope for self-report fear showed that the slope of pre-acquisition NA was nearly significantly higher than the slope of trait NA ($t(55) = 1.929$, $p = .059$) and postextinction NA ($t(55) = 1.748$, $p = .086$). Moreover, the linear slope of pre-acquisition NA did not significantly differ from pre-extinction NA ($t(55) = 1.420$, $p = .161$).

Reacquisition

In sum, there was significant differential reacquisition for all measures of fear (i.e. greater increase in fear to the CS+ than CS-).

For SCR, the quadratic slope was not significantly different from zero ($t(51) = -1.776$, $b = -0.030$, $SE = 0.017$, $p = .082$), so it was dropped from the model. In the linear model, the

intercept ($t(51) = 7.103$, $b = 0.278$, $SE = 0.039$, $p < .001$) and linear slope ($t(51) = 3.058$, $b = 0.038$, $SE = 0.012$, $p = .004$) were significantly greater than zero. There was a significant interaction between CS type and the linear slope with a greater increase in fear across trials for the CS+ than CS- ($t(253) = 3.056$, $b = 0.046$, $SE = 0.015$, $p = .002$).

For US expectancy, the intercept ($t(53) = 12.827$, $b = 4.822$, $SE = 0.376$, $p < .001$) and linear slope ($t(53) = 6.101$, $b = 3.265$, $SE = 0.535$, $p < .001$) were significantly greater than zero, and the quadratic slope was significantly less than zero ($t(53) = -5.326$, $b = -7.725$, $SE = 0.136$, $p < .001$). There was a significant interaction between CS type and the linear slope with a greater increase in fear across trials for the CS+ than CS- ($t(53) = 7.177$, $b = 4.186$, $SE = 0.583$, $p < .001$). There was also a significant interaction between CS type and the quadratic slope with a stronger deceleration for the CS+ than CS- ($t(53) = -4.850$, $b = -0.813$, $SE = 0.168$, $p < .001$).

For self-report fear, the intercept ($t(57) = 16.826$, $b = 3.414$, $SE = 0.203$, $p < .001$) and linear slope ($t(57) = 3.763$, $b = 0.944$, $SE = 0.251$, $p < .001$) were significantly greater than zero. There was a significant interaction between CS type and the linear slope with a greater increase in fear across trials for the CS+ than CS- ($t(57) = 6.273$, $b = 1.574$, $SE = 0.251$, $p < .001$).

Rates of Acquisition and Reacquisition

There were no significant interactions involving phase (acquisition, reacquisition) and slope for any of the measures of fear ($ps > .077$). Thus, the rate of change of fear was the same during acquisition and reacquisition.

PA and NA Predicting Reacquisition

See Table 2 for results regarding the effects of PA and NA on linear slope of SCR, US expectancy, and selfreport fear.

For SCR, higher pre-acquisition PA ($t(49) = -2.500$, $b = -0.044$, $SE = 0.017$, $p = .016$), pre-extinction PA ($t(49) = -2.297$, $b = -0.031$, $SE = 0.013$, $p = .026$), and post-extinction PA ($t(49) = -3.117$, $b = -0.041$, $SE = 0.013$, $p = .003$) predicted a significantly lower linear slope (see Figure 2 for effects of pre-extinction PA on SCR reacquisition). Higher pre-reacquisition PA trended towards significantly predicting a lower linear slope ($t(49) = -1.996$, $b = -0.028$, $SE = 0.014$, $p = .052$). Higher post-extinction PA also predicted a higher intercept ($t(49) = 2.420$, $b = 0.106$, $SE = 0.044$, $p = .019$). Furthermore, higher pre-acquisition PA ($t(349) = -2.335$, $b = 0.072$, $SE = 0.031$, $p = .020$) predicted the interaction with CS type and time, with PA predicting a decrease in the slope for the CS+ compared to the CS-. No other analyses involving state or trait PA and the intercept or slope were significant ($ps > .179$). Conversely, none of the NA time points nor trait NA were significant predictors of intercept or linear slope ($ps > .096$).

T-test comparisons of linear slopes for SCR showed that the slopes for pre-acquisition, preextinction, and post-extinction PA did not significantly differ from each other ($ps > .712$). Similarly, the slopes of pre-acquisition ($t(49) = -1.091$, $p = .281$), pre-extinction ($t(49) = -0.893$, $p = .376$), and post-extinction ($t(49) = -1.139$, $p = .260$) PA did not significantly differ from trait PA. The slopes of preacquisition ($t(49) = -0.713$, $p = .479$), pre-extinction ($t(49) = -0.687$, $p = .496$), and post-extinction ($t(49) = -0.709$, $p = .482$) PA also did not significantly differ from pre-reacquisition PA.

For US expectancy, pre-acquisition PA, pre-reacquisition PA, and trait PA did not significantly predict the intercept, linear slope, nor quadratic slope (p s > .076). Pre-acquisition PA did, however, predict the interaction between CS type and the linear slope with a lower slope for the CS+ than CS- ($t(51) = -2.037$, $b = -1.608$, $SE = 0.790$, $p = .047$). Higher post-extinction PA significantly predicted a lower linear slope ($t(51) = -2.253$, $b = -1.300$, $SE = 0.577$, $p = .029$) and a significant interaction between CS type and the linear slope with a lower slope for the CS+ than the CS- ($t(51) = -2.009$, $b = -1.275$, $SE = 0.635$, $p = .050$).

Similarly, higher pre-extinction PA significantly predicted a lower linear slope ($t(51) = -3.005$, $b = -2.117$, $SE = 0.704$, $p = .004$), a higher quadratic slope ($t(51) = 2.493$, $b = 0.456$, $SE = 0.183$, $p = .016$), the interaction between CS type and the linear slope with a lower slope for the CS+ than the CS- ($t(51) = 2.812$, $b = 2.175$, $SE = 0.773$, $p = .007$), and the interaction between CS type and the quadratic slope with a greater deceleration for the CS+ than CS- ($t(51) = 2.039$, $b = 0.466$, $SE = 0.229$, $p = .047$) (see Figure 3 for effects of pre-extinction PA on US expectancy reacquisition). None of the NA time points nor trait NA significantly predicted the intercept, linear slope, nor quadratic slope (p s > .116).

T-test comparisons of linear slopes for US expectancy showed that the slope of pre-extinction PA and post-extinction PA did not significantly differ from each other ($t(51) = -0.186$, $p = .853$). Pre-extinction PA did not significantly differ from pre-acquisition ($t(51) = -1.234$, $p = .223$) or pre-reacquisition PA ($t(51) = -0.928$, $p = .358$) but nearly significantly differed from trait PA ($t(51) = -1.893$, $p = .064$). Similarly, post-extinction PA did not significantly differ from pre-acquisition ($t(51) = -1.234$, $p = .296$) or pre-reacquisition PA ($t(51) = -0.738$, $p = .464$) but nearly significantly differed from trait PA ($t(51) = -1.704$, $p = .095$).

For the self-report fear linear model, none of the PA time points nor trait PA significantly predicted the intercept nor linear slope ($ps > .091$). Pre-acquisition NA significantly predicted the interaction between CS type and the linear slope with greater NA predicting a higher slope for the CS+ than CS- ($t(55) = 2.219$, $b = -1.264$, $SE = 0.569$, $p = .031$). Lower pre-reacquisition NA trended towards significantly predicting a lower slope ($t(55) = -1.990$, $b = -1.299$, $SE = 0.653$, $p = .052$). None of the NA time points nor trait NA significantly predicted linear slope ($ps > .134$). Trait NA ($t(55) = 2.217$, $b = 0.865$, $SE = 0.390$, $p = .031$), post-extinction NA ($t(55) = 2.971$, $b = 1.778$, $SE = 0.599$, $p = .004$), and pre-reacquisition NA ($t(55) = 3.825$, $b = 1.862$, $SE = 0.487$, $p < .001$) significantly predicted a higher intercept at reacquisition. No other time points for NA predicted the intercept.

Discussion

The present study evaluated the effects of positive affect (PA) and negative affect (NA) on reacquisition. Rapid reacquisition refers to increased conditional fear to the CS following re-pairing of the CS and US after extinction, with rate of fear increase typically greater than during initial acquisition. However, in the present study, the rates of fear increase across the acquisition and reacquisition phases were not significantly different. Thus, the reacquisition was not more “rapid” than acquisition. The study hypothesis was that higher PA before extinction would be associated with less reacquisition. The results supported this with two measures of fear (i.e. skin conductance arousal and expectancy for the aversive event) but not with self-report fear.

Fear conditioning generally followed expected trajectories. All measures of fear showed differential acquisition, extinction, and reacquisition. Expectancy for the aversive event and SCR showed differential spontaneous recovery, but self-report fear showed non-differential

spontaneous recovery. Given the limited number of human fear conditioning studies that have demonstrated reacquisition (Soeter & Kindt, 2010), the fact that we were able to demonstrate reacquisition is important in its own right. Like the other forms of return of fear, reacquisition has relevance for the treatment of anxiety disorders. Individuals can experience re-pairings of the CS (e.g. public speech) and aversive event (e.g. rejection) after therapy, which can cause an increase in fear to the CS. Methods employed during treatment to reduce fear caused by reacquisition can be vital to maintaining long-term fear reduction.

The results were partly supportive of our hypothesis that higher PA before extinction would be associated with less reacquisition. Due to high correlations between our measures of PA across different time points, we analysed each time point in a separate model. Thus, we were not able to evaluate the specificity of effects of pre-extinction PA relative to PA at other time points within a single analytical model. However, we were able to test the specificity of effects to PA relative to NA at the same time point within the same model.

Generally speaking, higher PA was associated with less reacquisition as measured by skin conductance arousal and expectancy for the aversive event (i.e. US expectancy) but not self-report fear. More specifically, pre-acquisition, pre-extinction, and postextinction PA were associated with less reacquisition as measured by skin conductance arousal. For expectancy of the aversive event, pre-extinction and postextinction PA were associated with less reacquisition. None of the measures of PA were significantly associated with reacquisition as measured by self-report fear. Thus, the results were most robust for PA before and after extinction. Though our measure of trait PA was not significantly associated with reacquisition fear, its linear slope did not significantly differ from measures of PA at other time points. Therefore, we cannot conclude that state PA is associated with less reacquisition compared to trait PA. Furthermore, none of the

measures of NA were significantly associated with reacquisition as measured by skin conductance arousal, expectancy for the aversive event, or self-report fear.

We also analysed the effects of PA and NA on acquisition, extinction, and spontaneous recovery. There were no effects of PA and NA on acquisition. During extinction, there were no effects other than higher trait PA being associated with a lower slope for self-report fear. PA was not associated with spontaneous recovery. However, higher pre-acquisition NA was associated with a higher slope of spontaneous recovery as measured by self-report fear. No other effects of NA were observed with the slope of spontaneous recovery. It is important to note, however, that this study was not well-designed to test spontaneous recovery. Future studies testing the effects of PA on spontaneous recovery would benefit from an experiment better designed to test it.

In total, the results showed that pre- and postextinction PA were most robustly associated with less reacquisition. This partly supports our hypothesis, which was that pre-extinction PA would be associated with less reacquisition. Given a correlation of .782 between pre- and post-extinction PA, the similarity in their results is not surprising, and they likely both reflect PA during extinction.

The findings suggest that individuals with high PA before and after (and, likely, during) exposure are less likely to experience a return of fear when their previously feared stimulus is repaired with an aversive event following completion of exposure therapy, the clinical proxy of extinction. For example, an individual with fear of public speaking who experiences rejection during a speech after exposure therapy would have less reacquisition of fear if PA were high before and after exposure than low. The findings further suggest that strategies designed to raise PA prior to or after exposure therapy may lessen the chances of return of fear through processes of reacquisition. Indeed, in an earlier study (Zbozinek, Holmes, et al., 2015), we found that the

induction of PA prior to extinction lessened subsequent reinstatement of fear, another pathway to the return of fear. Furthermore, while not directly targeting PA, we also found that training to positive information regarding the phobic stimulus improved the effects of exposure therapy in individuals fearful of spiders (Dour, Brown, & Craske, 2016). This may be related to increasing positive appraisal of the feared stimulus or counter-conditioning.

Our hypotheses were based on prior evidence for PA to enhance depth of encoding (Craik, 2002; Craik & Lockhart, 1972; Ellis et al., 1984; Isen et al., 1987; Kiefer et al., 2007) and rehearsal (Craik, 2002; Craik & Lockhart, 1972; Ellis et al., 1984; Isen et al., 1987), which both improve retrieval and long-term memory (Craik, 2002; Craik & Lockhart, 1972). By translation to extinction, PA may enhance the encoding, rehearsal, and retrieval of extinction learning. Furthermore, PA may facilitate the integration of incoming inhibitory learning with already-existing excitatory learning via relational processing (Clore & Huntsinger, 2007), such that greater activation of the inhibitory association occurs when the excitatory association is activated at a later time, as is the case during reacquisition. Conceivably, for individuals with high PA during extinction, the inhibitory memory was stronger during reacquisition, which protected against reacquisition. However, in the absence of measures of the purported mechanisms (e.g. encoding, rehearsal, and retrieval), the reasons why PA is associated with long-term retention of extinction learning cannot be determined in this study alone.

There were several limitations of the present study. First, we did not experimentally manipulate mood, and, thus, we cannot determine causality between PA and reacquisition. As such, we cannot determine whether a third variable is responsible for the results. Second, because acquisition and extinction were conducted on the same day, our measure of pre-extinction mood is also a measure of post-acquisition mood. Future studies would benefit from

having acquisition on one day and extinction on a second day. Third, the findings model a one-week interval between extinction and reacquisition. It is unclear how these results would extend over longer periods of time or multiple sessions of extinction, which would be relevant for treatment of anxious individuals. Fourth, our index of PA during extinction was measured immediately prior to and after extinction rather than throughout the course of extinction training. On the other hand, the high correlation between pre- and post-extinction PA suggests that they were reflective of affect during extinction. Future studies could separate the effects of pre- and post-extinction PA by randomising individuals to positive and negative mood inductions before and after extinction.

Fifth, the effects of PA were observed on measures of SCR and expectancy for the aversive event but were not observed with self-report fear. Although the various measures of “fear” as a construct often covary (Craske, Hermans, & Vansteenwegen, 2006), they are also frequently discordant (Hodgson & Rachman, 1977). This can occur for many reasons, such as measurement error and differences in sensitivity (Boddez et al., 2013), or it may be an indication that each measure captures a different aspect of “fear”. Skin conductance is considered to measure arousal (Bradley et al., 1990; Cook, Hawk, Davis, & Stevenson, 1991; Greenwald, Cook, & Lang, 1989; Manning & Melchiori, 1974; Winton, Putnam, & Krauss, 1984). US expectancy is not directly a measure of “fear”, but rather a measure of associative learning (i.e. the CS/US relationship). Hence, our results suggest that PA reduced arousal and the CS/US association during reacquisition. Self-report fear is a measure of the explicit emotion of being afraid and may not include other threat-relevant responding (LeDoux, 2014). Finally, generalisability of the findings to a clinically anxious sample awaits further investigation.

In conclusion, the present study suggests that higher PA before and after (and, likely, during) extinction is associated with less reacquisition. Our other work has shown that PA prior to extinction reduces reinstatement of conditional fear (Zbozinek, Holmes, et al., 2015). Testing awaits for the relations between PA and the two other pathways to return of fear: spontaneous recovery and renewal. Clinical translation of our findings would suggest that individuals with high PA before and after an exposure therapy session may be less vulnerable to a return of fear if their previously feared object or situation is re-paired with aversive outcomes. Furthermore, therapeutic strategies designed to raise PA before and after an exposure therapy session may augment the long-term outcomes of treatment.

Acknowledgments

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Table 1.

Overview of the experimental procedures with order of phases listed horizontally and order within phases listed vertically

Day 1			Day 8	
<i>Habituation</i>	<i>Acquisition</i>	<i>Extinction</i>	<i>Extinction Test</i>	<i>Reacquisition</i>
PANAS	8 CS+	PANAS	PANAS	
2 CS+, 2 CS-, 4 ITI	with 8 US, 8 CS-, 16 ITI	8 CS+, 8 CS-, 16 ITI	2 CS+, 2 CS-, 4 ITI	4 CS+ with 4 US, 4 CS-, 8 ITI
Self-Report Fear	Self-Report Fear	Self-Report Fear	Self-Report Fear	Self-Report Fear
		PANAS		

NOTE: CS+ is the conditional stimulus that, during acquisition, is paired with the unconditional stimulus (US; electric shock), CS- is associated with the absence of the US, ITIs are inter-trial intervals (i.e., the time between presentations of the CS+ and CS-), and PANAS is the Positive and Negative Affect Schedule.

Table 2.

The effects of positive and negative affect on reacquisition CS+ linear slope.

Dependent variable	Predictors	b	SE	t	df	p
SCR	Pre-acquisition PA	−0.044	0.017	−2.500	49	.016
	Pre-acquisition NA	0.013	0.031	0.438	49	.664
	Pre-extinction PA	−0.031	0.013	−2.297	49	.026
	Pre-extinction NA	0.096	0.049	1.955	49	.056
	Post-extinction PA	−0.041	0.013	−3.117	49	.003
	Post-extinction NA	0.055	0.041	1.362	49	.180
	Pre-reacquisition PA	−0.028	0.014	−1.996	49	.052
	Pre-reacquisition NA	−0.038	0.032	−1.163	49	.251
	Trait PA	−0.019	0.015	−1.231	49	.224
	Trait NA	−0.008	0.030	−0.253	49	.801
US expectancy	Pre-acquisition PA	−2.614	1.443	−1.812	51	.076
	Pre-acquisition NA	0.340	2.529	0.134	51	.894
	Pre-extinction PA	−2.117	0.704	−3.005	51	.004
	Pre-extinction NA	−0.398	2.090	−0.190	51	.850
	Post-extinction PA	−1.300	0.577	−2.253	51	.029
	Post-extinction NA	−0.398	1.749	−0.228	51	.821
	Pre-reacquisition PA	−0.687	0.596	−1.152	51	.255
	Pre-reacquisition NA	−0.989	1.421	−0.696	51	.490
	Trait PA	0.171	0.643	0.267	51	.791
	Trait NA	0.512	1.254	0.408	51	.685
Self-report fear	Pre-acquisition PA	−0.029	0.335	−0.085	55	.932
	Pre-acquisition NA	0.900	0.595	1.520	55	.134
	Pre-extinction PA	0.040	0.284	0.141	55	.888
	Pre-extinction NA	0.131	0.951	0.138	55	.891
	Post-extinction PA	0.042	0.285	0.148	55	.883

Post-extinction NA	−0.573	0.785	−0.730	55	.468
Pre-reacquisition PA	−0.014	0.278	−0.051	55	.959
Pre-reacquisition NA	−1.299	0.653	−1.990	55	.052
Trait PA	0.192	0.298	0.644	55	.522
Trait NA	−0.503	0.499	−1.008	55	.318

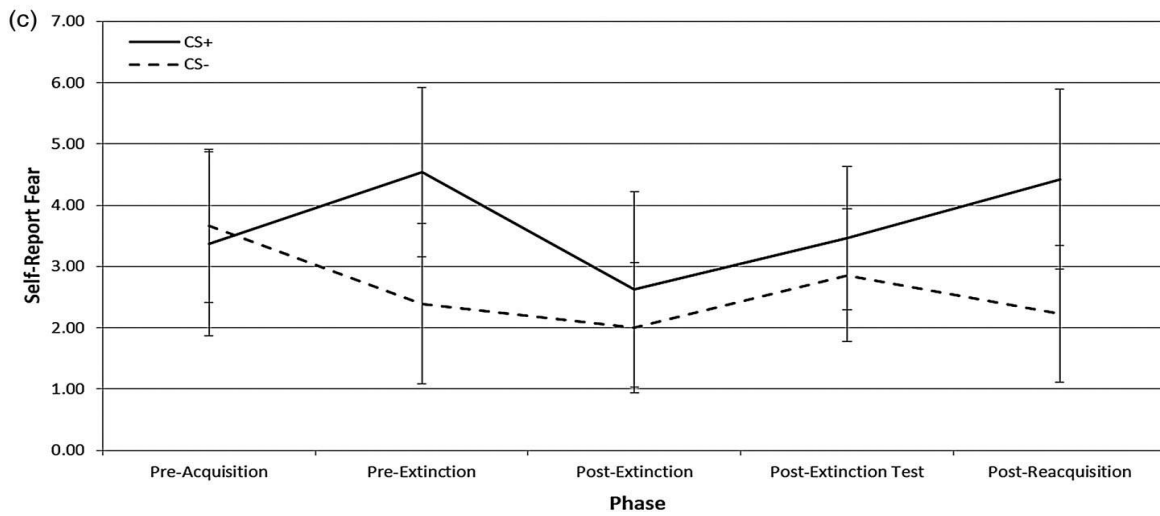
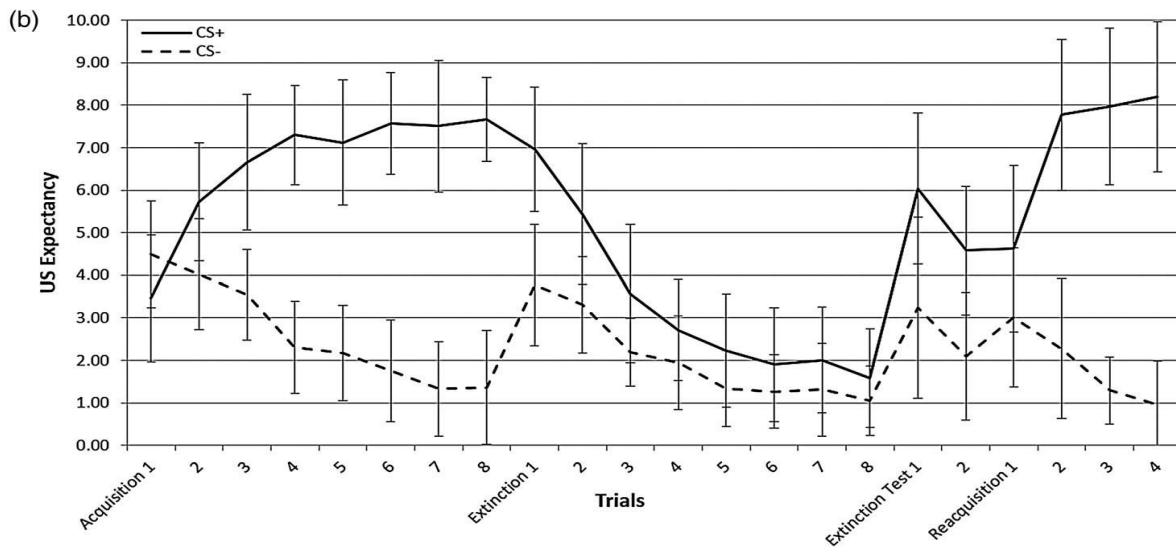
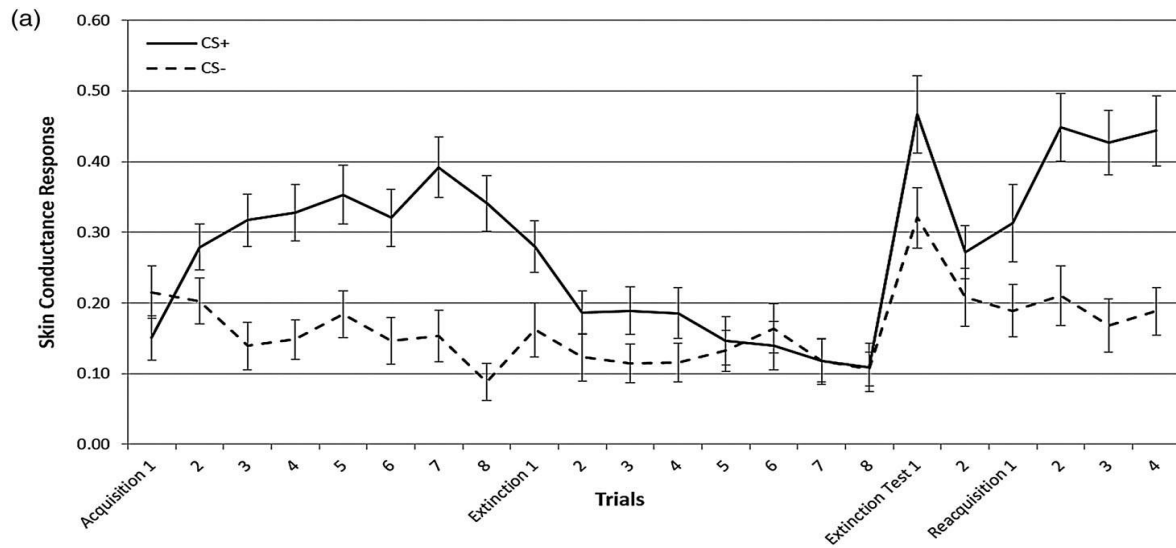


Figure 1.

(a–c) Present fear conditioning data across acquisition, extinction, extinction test, and reacquisition for the CS+ and CS– with SCR, US expectancy, and self-report fear. Error bars are standard errors. Significant differential acquisition, extinction, spontaneous recovery, and reacquisition were observed with all measures except self-report spontaneous recovery, which was a non-differential increase in fear. US expectancy was measured on a 0–9 scale, where 0 = “Certain no muscle stimulation”, 4.5 = “Uncertain”, and 9 = “Certain muscle stimulation”. Self-report fear measured on a 1–7 scale, where 1 = “Not at all fearful of” and 7 = “Very fearful of”.

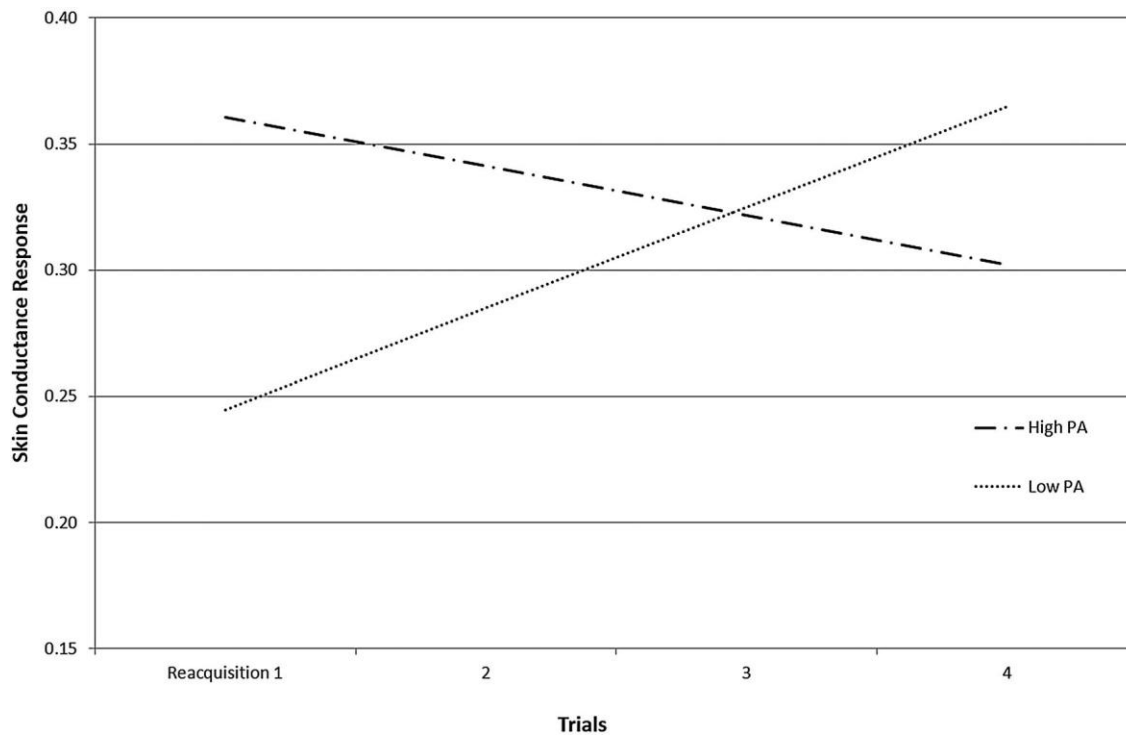


Figure 2.

Effect of pre-extinction PA on CS+ reacquisition – SCR. For illustrative purpose, the “high PA” and “low PA” lines on the graph display PA from the top and bottom quartiles of pre-extinction PA. Pre-extinction PA significantly predicts the linear slope ($t(49) = -2.297$, $b = -0.31$, $SE = 0.013$, $p = .026$) for SCR during reacquisition. Trial 1 shows responding before shock delivery.

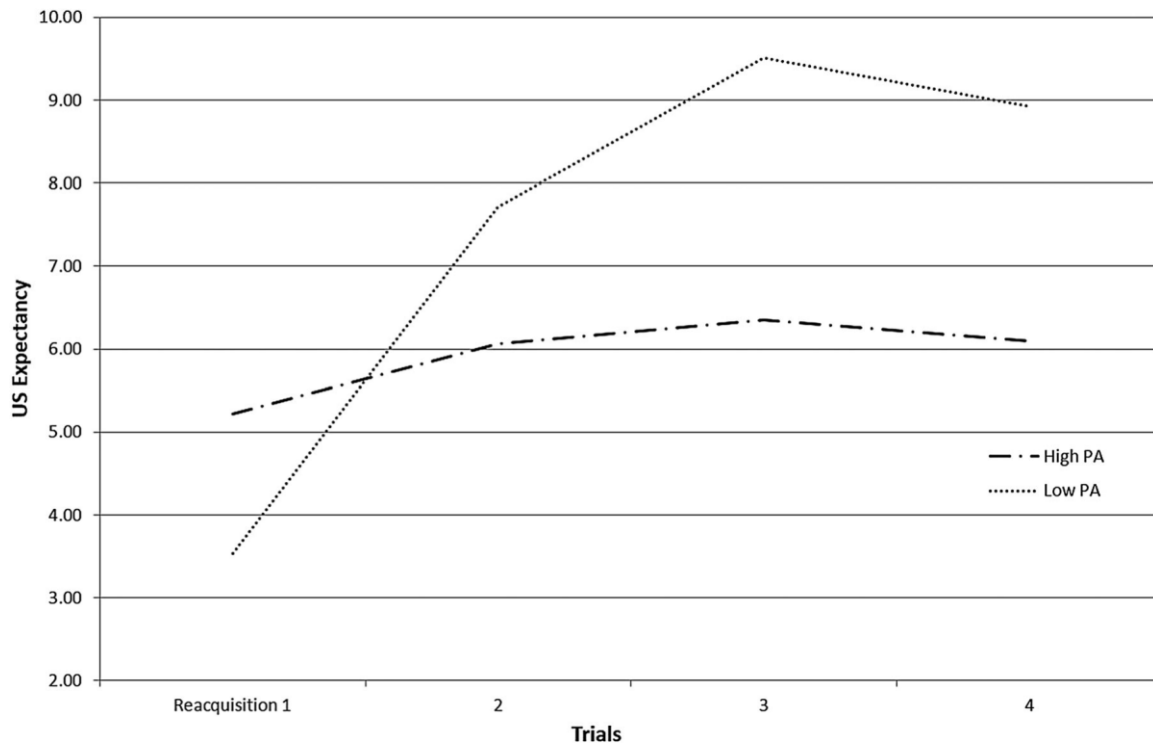


Figure 3.

Effect of pre-extinction PA on CS+ reacquisition – US expectancy. For illustrative purpose, the “high PA” and “low PA” lines on the graph display PA from the top and bottom quartiles of pre-extinction PA. Pre-extinction PA significantly predicts the linear slope ($t(51) = -3.005$, $b = -2.117$, $SE = 0.704$, $p = .004$) and quadratic slope ($t(51) = -2.493$, $b = -0.456$, $SE = 0.183$, $p = .016$).

Study 2: The Effects of Positive Mood Induction on Long-Term Extinction Learning,
Spontaneous Recovery, and Reacquisition

Introduction

The same rationale follows for Study 2 as for Study 1. In Study 2, higher PA during extinction may facilitate integration of extinction trials (i.e., incoming information) with previous acquisition trials (i.e., already-known information). By enhancing learning processes during extinction and increasing combined activation of the inhibitory and excitatory associations during extinction, the inhibitory association may be more active during reacquisition – when the excitatory association is activated. Additionally, increases in semantic processing during extinction may enhance deeper encoding of the inhibitory association, which may reduce return of fear. Thus, higher PA before extinction may be associated with lower levels of spontaneous recovery and reacquisition.

We hypothesized that, relative to a mood induction designed to decrease PA before extinction, a mood induction designed to substantially increase PA before extinction would be associated with a) greater long-term extinction learning, b) less spontaneous recovery, and c) less reacquisition of conditional fear. “Long-term extinction learning” refers to change in conditional fear from after acquisition to after consolidation of extinction and is operationalized herein as change in conditional fear from the last trial of acquisition to the first trial at extinction test, one week after extinction training. Spontaneous recovery refers to increases in fear from the end of extinction to a subsequent test of extinction, and is operationalized herein as change in conditional fear from the last trial of extinction to the first trial at extinction test, one week later. Rapid reacquisition refers to rate of increase in conditional fear when the CS+ is re-paired with the US following extinction, and is operationalized herein as change in conditional fear from the first to the fourth re-pairing of the CS+ with the US, one week after extinction training.

In Study 1 (Zbozinek & Craske, 2016), higher levels of PA were associated with less reacquisition as measured by US expectancy and skin conductance response (SCR). In the current study, we improve upon the previous study by experimentally manipulating PA and testing its effects on long-term extinction learning, spontaneous recovery, and reacquisition of fear.

Methods

Participants

Participants (N = 58) were students from the University of California, Los Angeles, who participated for course credit. Seven participants dropped out partway through the study, leaving 51 participants who completed the study. Participants were 75% female; mean age 21.181 (SD = 1.944) years; and 3.9% African-American, 45.1% Asian or Asian-American, 31.4% Caucasian, and 19.6% Hispanic/Latino. This study was approved by the University of California, Los Angeles Institutional Review Board, and all participants provided informed consent prior to commencing the study.

Design

Participants underwent habituation, acquisition, and extinction on Day 1. One week later (i.e., Day 8), an extinction test phase that measured spontaneous recovery and long-term extinction learning was followed by reacquisition. CS Type (CS+, CS-) and Time (CS trials 1, 2, etc.) were within-subject factors. Mood Induction (Positive mood induction (PMI), Negative mood induction (NMI)) was the between-subjects independent factor.

Materials and Apparatus

CS and US

The Pavlovian conditioning procedure was programmed using E-Prime 2 Professional Version 2.0.10.353. The CS+ and CS- were images of a Caucasian male and an Asian female

with neutral facial expressions (counterbalanced between participants). Facial images were chosen because human faces as CSs may be evolutionarily prepared and result in better conditioning than non-evolutionarily prepared CSs (e.g., lights, tones) (Lissek, et al., 2005; Öhman & Mineka, 2001). The CSs were displayed on a 21-inch computer monitor for 8 seconds located 3 feet from the participants at eye level. To maximize CS salience, the CSs covered most of the computer screen when displayed. The CSs were pseudo-randomized with no more than two consecutive presentations of the CS+ or the CS- in a given phase. Prior to CS+/US pairings (i.e., acquisition), each CS was presented twice to reduce novelty and responding (i.e., habituation). Inter-trial intervals (ITIs) were randomized to either 25 or 35 seconds and involved a white screen with a small black fixation cross in the center. The electric shock US was delivered to the dominant arm bicep using the STMEPM, two LEAD110A (BIOPAC, Inc.), and two Telectrode T716 Ag/AgCl electrodes. The CS+/US reinforcement rate during acquisition and reacquisition was 100%; participants received 8 shocks during acquisition and 4 shocks during reacquisition. The shock consisted of 10 consecutive pulses .05 seconds in duration, totaling .5 seconds. During the acquisition and reacquisition phases, the shock US began 7.5 seconds after every CS+ onset and co-terminated with the CS+. The intensity of the US was determined using a work-up procedure (see Procedures).

Mood Induction

Mood induction consisted of commercial videos ranging from 30 to 80 seconds. The PMI mood induction videos were high in positive valence (e.g., humorous potato chip commercials, humorous car commercials), and the NMI mood induction videos were low in positive valence (e.g., anti-drinking and driving commercials, anti-domestic violence commercials). As part of a larger study (Paulus, et al., in preparation), the commercials were rated by 25 individuals for

valence and arousal in a within-subjects design using the self-assessment manikin (Bradley & Lang, 1994) on 1-9 scales, where 1 = “unhappy” and 9 = “happy” on the valence scale, and 1 = “calm” and 9 = “excited” on the arousal scale. Using a 2 (Video Valence: PMI, NMI) x 12 (Video Number) repeated measures ANOVA, the PMI videos ($M = 7.297$, $SD = .710$) were rated as significantly more positive than the NMI commercials ($M = 2.380$, $SD = .83$) ($F(1,24) = 347.405$, $p < .001$, $\eta_p^2 = .935$). The PMI commercials ($M = 3.777$, $SD = 1.58$) were also rated as significantly less arousing than the NMI commercials ($M = 5.183$, $SD = 1.68$) ($F(1,24) = 22.063$, $p < .001$, $\eta_p^2 = .479$). With average arousal rating of all the commercials as a covariate, the PMI videos remained significantly more positive than the NMI videos ($F(1,22) = 13.929$, $p = .001$, $\eta_p^2 = .388$). In the present study, mood induction was conducted before extinction (10 videos) and halfway through extinction (2 videos) as a mood induction booster.

Self-Report Measures of Fear

US expectancy. To test explicit associative learning, participants were instructed to “Please continually rate how certain you are that you will receive muscle stimulation [*i.e.*, *electric shock*] in the next few moments both when the reminders are present and absent.” Reminder prompts appeared at the bottom of the screen saying “Muscle Stimulation?” during the first three seconds of each ITI and CS. The values ranged from 0 = “Certain no muscle stimulation”, 4.5 = “Uncertain,” and 9 = “Certain muscle stimulation.” US expectancy was calculated as the mean rating 6.5-7 seconds after CS and ITI onset. This time frame was chosen as the point closest to potential US occurrence (7.5 seconds after CS+ onset during acquisition and reacquisition) without interfering with other measures.

Self-Report Fear. When presented with a small image of the CS+ or CS- in the top left corner of the computer screen, participants rated “how fearful this image makes you feel” using a

1-7 scale, where 1 = “Not at all fearful”, 4 = “Moderately fearful,” and 7 = “Very fearful.”

Images terminated upon completion of the fear rating. Self-report fear was measured before and after acquisition, after extinction, before extinction test, and before and after reacquisition.

Psychophysiological Measures of Fear

BIOPAC MP150 hardware unit and AcqKnowledge version 4.2 software (BIOPAC Systems, Inc.) were used to acquire all physiological data.

Skin conductance response (SCR). SCRs were recorded as a measure of arousal from two EL507 11mm diameter Ag/AgCl electrodes placed on the distal phalanx of the index and middle fingers of the non-dominant hand (e.g., Bradley, Cuthbert, & Lang, 1990). Using a GSR100C amplifier and two LEAD110A, SCR data were sampled at a rate of 31.25 Hz and filtered using an FIR low pass filter with a frequency cutoff fixed at 2Hz. SCR was calculated as a difference score between the maximum skin conductance value 1 to 6 seconds after CS onset minus the mean skin conductance value of the 2 seconds prior to CS onset. SCR was range-corrected by dividing by the largest SCR per participant across both days. SCRs that were greater than zero were square root transformed to normalize the data. SCRs less than or equal to zero were coded as zero.

Startle Reflex. The startle reflex was measured with electromyography (EMG) orbicularis oculi activity under the left eye using two EL254S 4mm Ag/AgCl electrodes with the EMG100C amplifier. Electrode placement was 1cm beneath the outer corner of the eye. The second electrode was placed 1cm medial to the first electrode and 1cm beneath the bottom eyelid so the pair of electrodes run parallel to the bottom eyelid (Fridlund & Cacioppo, 1986). The startle probes (i.e., acoustic startle stimuli delivered to elicit eye blink startle reflexes) consisted of 50 milliseconds, 102 dB bursts of “white noise” with an instantaneous rise time delivered binaurally

through stereophonic headphones. Startle probes occurred 7 seconds after CS onset and were randomized to occur 10, 15, or 25 seconds after onset of the inter-trial interval (i.e., ITI), averaging at 16.25 seconds. Habituation prior to acquisition (Day 1) and extinction test (Day 2) consisted of 10 startle probes across a 2.5-minute period during a blank white screen. EMG data were sampled at a rate of 2kHz. The data were filtered using an FIR band pass filter with a low frequency cutoff of 60Hz and a high frequency cutoff of 500Hz. Data were then converted to an absolute value and smoothed using .005 samples mean value smoothing. Startle reflex was calculated as the difference between the absolute maximum EMG level in volts during the 20ms-150ms immediately after the startle probe and the mean EMG level in volts during the 200ms immediately preceding the startle probe. EMG data were then transformed into a within-subjects t-score using responses to all CSs and ITIs across both days (startle habituation trials were excluded from t-score calculations).

Measure of Affect

Positive and Negative Affect Schedule (PANAS; Watson & Clark, 1994; Watson, Clark, & Tellegen, 1988). Participants completed the PANAS before habituation, before and after mood induction, after extinction, and prior to extinction test to measure state PA and NA: “right now (that is, in the present moment).” Our measure of PA included a composite score of the Joviality, Self-Assurance, and Attentiveness subscales. The measure of NA was the general NA scale. In the present study, Cronbach’s α was .96 for PA and .93 for NA. The purpose of the PANAS was for manipulation check and to be a moderator of results.

Procedure

The experiment consisted of two assessments one week apart (i.e., Day 1 and Day 8). On Day 1, participants provided informed consent, physiological equipment was attached, and a

shock workup procedure was conducted. Shocks started at a low intensity and increased to the level a participant considered “uncomfortable but not painful” ($M = 6.464$, $SD = .763$) using a 0-10 discomfort scale (0 = “Not at all,” 5 = “Moderately,” and 10 = “Very”). Participants were then trained to use the US expectancy dial. The primary experimental phases occurred in the following sequence: startle habituation, habituation (2 CS+ and 2 CS-), acquisition (8 CS+/US and 8 CS-), mood induction (10 videos), extinction part 1 (4 CS+ and 4 CS-), mood induction booster (2 videos), extinction part 2 (4CS+, 4 CS-). On Day 8, after physiological equipment was attached and participants were reminded how to use the US expectancy dial, procedures included startle habituation, extinction test phase (2 CS+ and 2 CS-), and reacquisition (4 CS+/US, 4 CS-).

Data Analysis

Repeated measures ANOVAs typically are conducted when analyzing fear conditioning (e.g., Balooch, Neumann, & Boschen, 2012). Though this is a valid approach, multilevel modeling (Bryk & Raudenbush, 1992) improves the validity of the results (Kristjansson, Kircher, & Webb, 2007). ANOVAs derive group-level variance and consider all individual-level variance as error, whereas multilevel modeling derives both individual-level and group-level variance. “Individual-level” and “group-level” are relative terms in multilevel modeling. They can refer to individuals within groups, or repeated measures within individuals. The present study employed repeated measures within individuals, an approach to partitioning of variance that is particularly beneficial to psychophysiological measures that typically vary over trials (Marwitz & Stemmler, 1998). Multilevel models also better accommodate missing data, unbalanced designs, and unequal spacing of measurement occasions (Kristjansson, Kircher, & Webb, 2007).

Multilevel modeling for acquisition, extinction, long-term extinction learning, and reacquisition included growth curve models (Bryk & Raudenbush, 1992), as has been used in

prior fear conditioning studies (e.g., Gazendam, et al., 2015; Pineles, Vogt, & Orr, 2009; Zbozinek & Craske, 2016). Growth curve modeling is suitable for analyzing intercepts and slopes across repeated measures of fear within individuals. The intercept refers to the first time point in a series of repeated measures. The linear slope refers to the rate of change in values across repeated measures, and the quadratic slope refers to change in linear slope across repeated measures (i.e., acceleration/deceleration of linear slope). Rate of change during the first four trials of acquisition and the four trials of reacquisition were examined to assess whether reacquisition occurred at a faster rate than acquisition (i.e., “rapid reacquisition”).

The effects of Mood Induction on PA and NA were conducted using 2 (Mood Induction: PMI, NMI) x 2 (Time: before, after mood induction) repeated measures ANOVAs using SPSS Version 22.0. Tests of fear conditioning phases (i.e., acquisition, extinction, long-term extinction learning, spontaneous recovery, and reacquisition), involved multilevel models with repeated measures as a level 1 factor and individuals as a level 2 factor. Level 1 predictors included CS Type (CS+, CS-), Linear Slope (Trial 1, Trial 2, etc.), and Quadratic Slope (Trial 1, Trial 2, etc.). The CS+ was coded as 1, and the CS- was coded as 2. Thus, negative test statistics would indicate greater fear for the CS+. If the quadratic slope was not significant or if the analysis only involved two time points (e.g., spontaneous recovery, analyses of self-report fear), the quadratic slope was removed from the model. Mood Induction (PMI, NMI) was a Level 2 predictor. Dependent variables were US expectancy, SCR, startle reflex, and self-report fear. Analyses comparing rates of change between acquisition and reacquisition only included the CS+ to reduce model complexity. The level 1 predictors were Phase (Acquisition, Reacquisition), Linear Slope (Trials 1-4), and, if both acquisition and reacquisition had significant quadratic effects, Quadratic Slope (Trials 1-4). Multilevel models were conducted using STATA 13.0.

Results

Habituation

To test for initial differences, the first CS trial during habituation was analyzed using a 2 (CS Type: CS+, CS-) x 2 (CS Image: Male, Female) x 2 (Mood Induction: Positive mood induction (PMI), Negative mood induction (NMI)). The ANOVA failed to indicate any main effects or interactions for US expectancy, SCR, or startle reflex ($ps > .209$). Similarly, there were no effects for self-report fear after the habituation phase ($ps > .110$).

Acquisition

See Figure 1 for acquisition effects. For US expectancy, there was a significant CS Type (CS+, CS-) x Linear Slope (Trials 1-8) interaction ($Z = -13.28$, $p < .001$) with a significantly steeper incline for the CS+ than the CS-. There was also a significant CS Type (CS+, CS-) x Linear Slope (Trials 1-8) x Quadratic Slope (Trials 1-8) interaction ($Z = 7.43$, $p < .001$) with greater deceleration for the CS+ than the CS- (i.e., the CS+ approached a maximum asymptote, whereas the CS- approached a minimum asymptote).

For SCR, there was a significant CS Type (CS+, CS-) x Linear Slope (Trials 1-8) interaction ($Z = -6.73$, $p < .001$) with a significantly steeper incline for the CS+ than the CS-. There was also a significant CS Type (CS+, CS-) x Linear Slope (Trials 1-8) x Quadratic Slope (Trials 1-8) interaction ($Z = 3.82$, $p < .001$) with greater deceleration for the CS+ than the CS- (i.e., the CS+ approached a maximum asymptote, whereas the CS- approached a minimum asymptote).

For startle reflex, there was a significant CS Type (CS+, CS-) x Linear Slope (Trials 1-8) interaction ($Z = -2.57$, $p = .010$) with a significantly steeper incline for the CS+ than the CS-.

Though the Quadratic Slope effect was significant ($Z = -2.08$, $p = .038$), it did not significantly interact with CS Type and Linear Slope ($Z = 1.76$, $p = .079$).

For self-report fear, there was a significant CS Type (CS+, CS-) x Linear Slope (before acquisition, after acquisition) interaction ($Z = -9.71$, $p < .001$) with a significantly steeper incline for the CS+ than the CS-.

Mood Induction

See Figure 2 for the effects of Mood Induction on PA and NA. For PA, there was a significant Mood Induction (PMI, NMI) x Time (before mood induction, after mood induction) interaction ($F(1,56) = 38.66$, $p < .001$, $\eta_p^2 = .408$). Simple effects showed that the PMI group significantly increased PA from before ($M = 2.289$, $SD = .785$) to after ($M = 2.994$, $SD = .786$) mood induction ($F(1,56) = 28.80$, $p < .001$, $\eta_p^2 = .340$). Conversely, the NMI group significantly decreased PA from before ($M = 2.238$, $SD = .728$) to after ($M = 1.931$, $SD = .507$) mood induction ($F(1,56) = 11.74$, $p = .001$, $\eta_p^2 = .173$). Furthermore, there was no significant difference in PA before mood induction ($F(1,56) = .21$, $p = .646$, $\eta_p^2 = .004$), but there was significantly greater PA in the PMI group than the NMI group after mood induction ($F(1,56) = 37.49$, $p < .001$, $\eta_p^2 = .401$).

For NA, there was a significant Mood Induction (PMI, NMI) x Time (before mood induction, after mood induction) interaction ($F(1,56) = 34.82$, $p < .001$, $\eta_p^2 = .383$). Simple effects showed that the PMI group significantly decreased NA from before ($M = 1.928$, $SD = .528$) to after ($M = 1.459$, $SD = .663$) mood induction ($F(1,56) = 15.42$, $p < .001$, $\eta_p^2 = .216$). Conversely, the NMI group significantly increased NA from before ($M = 1.586$, $SD = .582$) to after ($M = 2.114$, $SD = .834$) mood induction ($F(1,56) = 19.52$, $p < .001$, $\eta_p^2 = .258$).

Unexpectedly, there was significantly greater NA before mood induction in the PMI group than the NMI group ($F(1,56) = 5.48, p = .023, \eta_p^2 = .089$). Conversely, there was significantly less NA affect in the PMI group than the NMI group after mood induction ($F(1,56) = 10.97, p = .002, \eta_p^2 = .164$).

Extinction

For US expectancy, there was a significant CS Type (CS+, CS-) x Linear Slope (Trials 1-8) interaction ($Z = 4.60, p < .001$) with a significantly steeper decline for the CS+ than the CS-. There was also a significant CS Type (CS+, CS-) x Linear Slope (Trials 1-8) x Quadratic Slope (Trials 1-8) interaction ($Z = -2.36, p = .018$) with greater acceleration for the CS+ than the CS-.

For SCR, there was no significant effect of Quadratic Slope ($Z = 1.19, p = .234$), so the quadratic effect was dropped from the model. In the linear model, there was no significant CS Type (CS+, CS-) x Linear Slope (Trials 1-8) interaction ($Z = 0.61, p = .544$). Also, while there was no main effect of CS Type ($Z = -1.71, p = .088$), there was a significant main effect of Linear Slope ($Z = -3.01, p = .033$) with a decline in SCR overall.

For startle reflex, there was no significant CS Type (CS+, CS-) x Linear Slope (Trials 1-8) interaction ($Z = -.64, p = .522$), nor was there a significant CS Type (CS+, CS-) x Linear Slope (Trials 1-8) x Quadratic Slope (Trials 1-8) interaction ($Z = 1.36, p = .175$). While there was no main effect of CS Type ($Z = -0.63, p = .530$), there was a significant main effect of Linear Slope ($Z = -4.46, p < .001$) with a decline in startle reflex and a significant effect of Quadratic Slope ($Z = 2.50, p = .012$) with an increase in slope as the slopes approached a minimum asymptote.

For self-report fear, there was a significant CS Type (CS+, CS-) x Linear Slope (after acquisition, after extinction) interaction ($Z = 7.19$, $p < .001$) with a significantly steeper decline for the CS+ than the CS-.

Long-Term Extinction Learning

In sum, there was significant differential extinction learning (i.e., greater decrease in fear to the CS+ than the CS- from end of acquisition to extinction test) for US expectancy and self-report fear. SCR showed greater fear to the CS+ than the CS- at both time points but no change across time. Startle reflex showed a main effect increase across time but no differences between CS+ and CS-. Lastly, Mood Induction did not significantly reduce fear via any measure across time.

For US expectancy, there was a significant CS Type (CS+, CS-) x Linear Time (last trial of acquisition, first trial of test) interaction ($Z = 3.73$, $p < .001$). Simple effects showed there was a significantly lower slope for the CS+ than the CS- ($Z = 8.00$, $p < .001$). Mood Induction was not involved in any significant effects involving Time ($ps > .333$).

For SCR, there was no significant CS Type (CS+, CS-) x Linear Time (last trial of acquisition, first trial of test) interaction ($Z = 0.02$, $p = .987$). There was a significant main effect of CS Type ($Z = -2.61$, $p = .009$) with significantly greater SCR for the CS+, but there was no main effect of Linear Time ($Z = 1.39$, $p = .163$). Mood Induction was not involved in any significant effects involving Time ($ps > .219$).

For startle reflex, there was no significant CS Type (CS+, CS-) x Linear Time (last trial of acquisition, first trial of test) interaction ($Z = 1.33$, $p = .183$). While there was no significant main effect of CS Type ($Z = -1.39$, $p = .163$) there was a main effect of Linear Time ($Z = 4.39$, p

< .001) with an increase in startle reflex from the last trial of acquisition to the first test trial. Mood Induction was not involved in any significant effects involving Time (p s > .070).

For self-report fear, there was a significant CS Type (CS+, CS-) x Linear Time (after extinction, extinction test) interaction ($Z = -4.52$, $p < .001$) with a significantly lower slope for the CS+ than the CS- ($Z = 4.38$, $p < .001$). Mood Induction was not involved in any significant effects involving Time (p s > .521).

Spontaneous Recovery

In sum, there was significant differential spontaneous recovery (i.e., greater increase in fear to the CS+ than the CS- from end of extinction to extinction test) for US expectancy. For SCR, startle reflex, and self-report fear, there was a main effect increase in fear across time. There were no significant effects involving Mood Induction.

For US expectancy, there was a significant CS Type (CS+, CS-) x Linear Time (last trial of extinction, first trial of test) interaction ($Z = -3.52$, $p < .001$) with a significantly higher slope for the CS+ than the CS- ($Z = -4.18$, $p < .001$). Mood Induction was not involved in any significant main or interaction effects (p s > .167).

For SCR, there was no significant CS Type (CS+, CS-) x Linear Time (last trial of extinction, first trial of test) interaction ($Z = -1.59$, $p = .113$). However, while there was no main effect of CS Type ($Z = -0.36$, $p = .716$), there was a main effect of Linear Time with an increase in SCR ($Z = 4.99$, $p < .001$). Mood Induction was not involved in any significant effects involving Time (p s > .430).

For startle reflex, there was no significant CS Type (CS+, CS-) x Linear Time (last trial of extinction, first trial of test) interaction ($Z = -0.11$, $p = .916$). However, while there was no

main effect of CS Type ($Z = 0.74$, $p = .460$), there was a main effect of Linear Time with an increase in startle reflex ($Z = 7.44$, $p < .001$). Mood Induction was not involved in any significant effects involving Time ($ps > .207$).

For self-report fear, there was no significant CS Type (CS+, CS-) x Linear Time (after extinction, extinction test) interaction ($Z = -1.75$, $p = .080$). However, while there was no main effect of CS Type ($Z = -1.38$, $p = .168$), there was a main effect of Linear Time with an increase in self-report fear ($Z = 2.73$, $p = .006$). Mood Induction was not involved in any significant effects involving Time ($ps > .377$).

Reacquisition

In sum, the NMI group showed higher SCR at the first trial of reacquisition than the PMI group (see below). For startle reflex, there was a main effect decrease in time, a main effect of CS Type with greater CS+ startle reflex, and no effects of Mood Induction. Thus, fear was not successfully reacquired as measured by startle reflex. For US expectancy and self-report fear, there was differential reacquisition (i.e., greater increase in CS+ fear than CS- fear) but no interactions between Mood Induction and Time.

For US expectancy, there was a significant CS Type (CS+, CS-) x Linear Time (Trials 1-4) interaction ($Z = -6.39$, $p < .001$) with a significantly higher slope for the CS+ than the CS- ($Z = -10.07$, $p < .001$). There was also a significant CS Type (CS+, CS-) x Linear Time (Trials 1-4) x Quadratic Time (Trials 1-4) interaction ($Z = 4.40$, $p < .001$) with greater deceleration for the CS+ than the CS-. There were no significant effects involving Mood Induction ($ps > .787$).

For SCR, there was no significant Quadratic Time effect ($Z = -0.52$, $p = .605$). Thus, the quadratic effect was dropped from the model. In the linear model, there was a significant CS

Type (CS+, CS-) x Linear Time (Trials 1-4) interaction ($Z = -3.92, p < .001$). There was also a significant Mood Induction (positive mood induction, negative mood induction) x CS Type (CS+, CS-) x Time (Trials 1-4) interaction ($Z = -2.30, p = .022$). Simple effects showed that there was a significantly greater slope for the positive mood induction group compared to the negative mood induction group for the CS+ ($Z = 2.31, p = .042$) but not the CS- ($Z = -.94, p = .698$) (see Figure 3). Visual inspection of Figure 3 shows that SCR during the CS+ differs between the positive mood induction and negative mood induction groups for the first trial only. Statistical analysis confirms that the negative mood induction group had significantly higher SCR than the positive mood induction group only for the first trial of reacquisition ($Z = -2.47, p = .013$); there is no significant difference during trials 2 through 4 ($ps > .160$). Importantly, the SCR measured during the first trial occurs prior to delivery of the first reacquisition shock, so it does not measure reacquisition itself, but rather fear immediately prior to reacquisition. Thus, the Mood Induction x CS Type x Time effect seems to be driven by a higher initial fear prior to reacquisition for the NMI group rather than changes in slope that occur after the first reacquisition trial.

For startle reflex, there was no significant Quadratic Time effect ($Z = 0.01, p = .989$). Thus, the quadratic effect was dropped from the model. In the linear model, there was no significant CS Type (CS+, CS-) x Linear Time (Trials 1-4) interaction ($Z = -0.51, p = .607$). However, there was a significant main effect of CS Type ($Z = -3.10, p = .002$) with greater startle reflex during the CS+ than the CS-, as well as a main effect of Linear Time ($Z = -2.10, p = .035$) with a decrease in startle reflex across time. Mood Induction was not involved in any significant effects involving Time ($ps > .787$).

For self-report fear, there was a significant CS Type (CS+, CS-) x Linear Time (before reacquisition, after reacquisition) interaction ($Z = -5.14$, $p < .001$) with a significantly higher slope for the CS+ than the CS- ($Z = -6.69$, $p < .001$). Mood Induction was not involved in any significant effects involving Time ($ps > .201$).

Rates of Acquisition and Reacquisition

In sum, there was a significantly lower CS+ slope during reacquisition than acquisition for SCR and startle reflex but no differences in slopes for US expectancy and self-report fear. Thus, reacquisition was slower than acquisition for SCR and startle reflex.

For US expectancy, there was no significant Phase (Acquisition, Reacquisition) x Linear Time (Trials 1-4) interaction for the CS+ ($Z = 0.95$, $p = .340$). Similarly, the Phase (Acquisition, Reacquisition) x Linear Time (Trials 1-4) x Quadratic Time (Trials 1-4) interaction was not significant ($Z = -1.04$, $p = .299$). Thus, reacquisition of US expectancy did not differ from acquisition. Furthermore, there were no significant effects involving Mood Induction and Phase ($ps > .654$).

For SCR, there was no significant Phase (Acquisition, Reacquisition) x Linear Time (Trials 1-4) interaction for the CS+ ($Z = 0.95$, $p = .340$). Similarly, the Phase (Acquisition, Reacquisition) x Linear Time (Trials 1-4) x Quadratic Time (Trials 1-4) interaction was not significant ($Z = -1.04$, $p = .299$). Thus, reacquisition of US expectancy did not differ from acquisition. Furthermore, there were no significant effects involving Mood Induction and Phase ($ps > .654$).

For startle reflex, there was a significant Phase (Acquisition, Reacquisition) x Linear Time (Trials 1-4) interaction for the CS+ ($Z = -2.64$, $p = .001$). Simple effects showed that there

was a significantly lower linear slope during reacquisition than acquisition ($Z = -2.49$, $p = .013$). Similarly, the Phase (Acquisition, Reacquisition) $\times$ Linear Time (Trials 1-4) $\times$ Quadratic Time (Trials 1-4) interaction was significant ($Z = 2.29$, $p = .022$) with a great deceleration during acquisition than reacquisition. Thus, slope of startle reflex was slower during reacquisition than acquisition. Furthermore, there were no significant effects involving Mood Induction and Phase ($ps > .673$).

For self-report fear, there was no significant Phase (Acquisition, Reacquisition) $\times$ Linear Time (Trials 1-2) interaction for the CS+ ($Z = -0.91$, $p = .365$). Thus, reacquisition of US expectancy did not differ from acquisition. Furthermore, there were no significant effects involving Mood Induction and Phase ($ps > .535$).

Discussion

The present study evaluated the effects of pre-extinction mood induction on changes in conditional fear 1) from the end of acquisition to a test trial one week later (i.e., long-term extinction learning), 2) from the end of extinction to a test trial one week later (i.e., spontaneous recovery), and 3) over re-pairings of the conditional stimulus and aversive stimulus one week after extinction (i.e., reacquisition). The primary study hypothesis was that induced positive mood before and during extinction would lessen fear relative to induced negative mood across various indices of extinction learning and return of fear.

Viewing positive commercials successfully increased positive affect and decreased negative affect relative to viewing more negative commercials. Overall, the results showed that there were no effects of mood induction on long-term extinction learning, spontaneous recovery, or reacquisition of fear. The negative mood induction group had higher skin conductance arousal

than the positive mood induction group at the first trial of reacquisition but not during other trials. Because this skin conductance arousal data was recorded prior to the delivery of the first aversive unconditional stimulus, this does not reflect fear as a result of reacquisition, nor does it reflect spontaneous recovery or long-term extinction learning, which were assessed in previous conditional stimulus trials. Thus, interpretability of this finding is limited.

In translation to the clinical context of exposure therapy, the findings suggest that mood prior to and during an exposure will not affect changes in fear levels that result from the passage of time since the last exposure or when the previously feared stimulus is re-paired with an aversive event following completion of exposure therapy. This is in contrast with our previous findings (Study 1; Zbozinek & Craske, 2016), which showed that higher positive affect before and after extinction was associated with less reacquisition of fear as measured with expectancy for the aversive event and skin conductance arousal. However, Zbozinek & Craske (2016) was limited because it lacked experimental manipulation of mood. Thus, it is possible that an unknown third variable from that study which covaried with positive affect may have been responsible for those results. If indeed a separate third variable was responsible for those results, this could explain why experimental manipulation of mood in the present study did not result in decreased fear – the incorrect variable may have been manipulated in the present study.

Alternatively, perhaps positive affect may still indeed lead to less fear, but methodological limitations of the present study may have prevented our observation of this. For example, arousal may have confounded the results and may explain the null effects of mood induction. The negative video clips in the present study were rated as significantly more arousing than the positive video clips. It has been demonstrated that increased arousal enhances long-term memory of emotional material (Cahill & McGaugh, 1995, 1998; McGaugh, 2006), though these

studies tend to focus on post-learning arousal and its impact on consolidation of learning. In the present study, increased arousal was likely confounded with increased negative affect and decreased positive affect. Thus, individuals in the negative video group likely experienced greater arousal during extinction than the positive video group. The hypothesized beneficial effects of positive affect on inhibitory learning may have been counteracted by the memory-enhancing effects of increased arousal in the negative video group, which may have mitigated group differences. Additionally, our present study differed from Zbozinek and Craske (2015) by introducing a mid-extinction mood induction booster. Theoretically from the positive affect perspective, this was done to maintain mood separation throughout extinction and potentially increase effect size. However, from a fear conditioning perspective, this likely resulted in disinhibition and may have interrupted or had unintended effects on the extinction learning process. Future studies may benefit from matching positive and negative mood inductions on levels of arousal and not interrupting extinction with a mood induction.

Our hypotheses were based on prior evidence for positive affect to increase semantic processing and enhance depth of encoding (Craig, 2002; Craig & Lockhart, 1972; Ellis, Thomas, & Rodriguez, 1984; Isen, Daubman, & Nowicki, 1987; Kiefer, et al., 2007) and rehearsal (Craig, 2002; Craig & Lockhart, 1972; Ellis, Thomas, & Rodriguez, 1984; Isen, Daubman, & Nowicki, 1987), which both improve retrieval and long-term memory (Craig, 2002; Craig & Lockhart, 1972). We have hypothesized that positive affect may enhance the encoding, rehearsal, and retrieval of extinction learning (Zbozinek & Craske, 2016). Furthermore, positive affect may facilitate the integration of incoming inhibitory learning with already-existing excitatory learning via relational processing (Storbeck & Clore, 2007), such that greater activation of the inhibitory association occurs when the excitatory association is activated at a later time, as is the case

during reacquisition. Similarly, positive mood induction during extinction is likely to lead to deeper encoding during extinction, thereby reducing both spontaneous recovery and reacquisition of fear. However, these effects were not observed in the present study.

Only a limited number of human fear conditioning studies have demonstrated reacquisition of conditional fear (e.g., Soeter & Kindt, 2011; Zbozinek & Craske, 2016). The fact that we were able to demonstrate reacquisition with US expectancy, skin conductance arousal, and self-report fear is important in its own right. Like other forms of return of fear, reacquisition has relevance for the treatment of anxiety disorders. Individuals can experience re-pairings of the conditional stimulus (e.g., public speech) and aversive event (e.g., ridicule) after therapy, which can cause an increase in fear to the conditional stimulus. Therapeutic strategies to reduce fear caused by subsequent reacquisition is an important avenue for future research (e.g., occasional reinforcement during extinction; Bouton, Woods, & Pineño, 2004). However, in contrast to some animal studies (e.g., Napier, et al., 1992), the rate of reacquisition was not faster than acquisition and in fact was slower with skin conductance arousal. Thus, similar to our previous study (Zbozinek & Craske, 2016), reacquisition in this study was not more “rapid” than acquisition. This may suggest that the original excitatory memory did not affect reacquisition. Alternatively, this observation may result from methodology. The speed of reacquisition can also be tested by comparing the rate of conditional fear increase between re-pairings of the original CS+ and US and the pairing of a novel CS+ and the US (Napier, et al., 1992). Future studies investigating fear reacquisition in humans may benefit from employing this method.

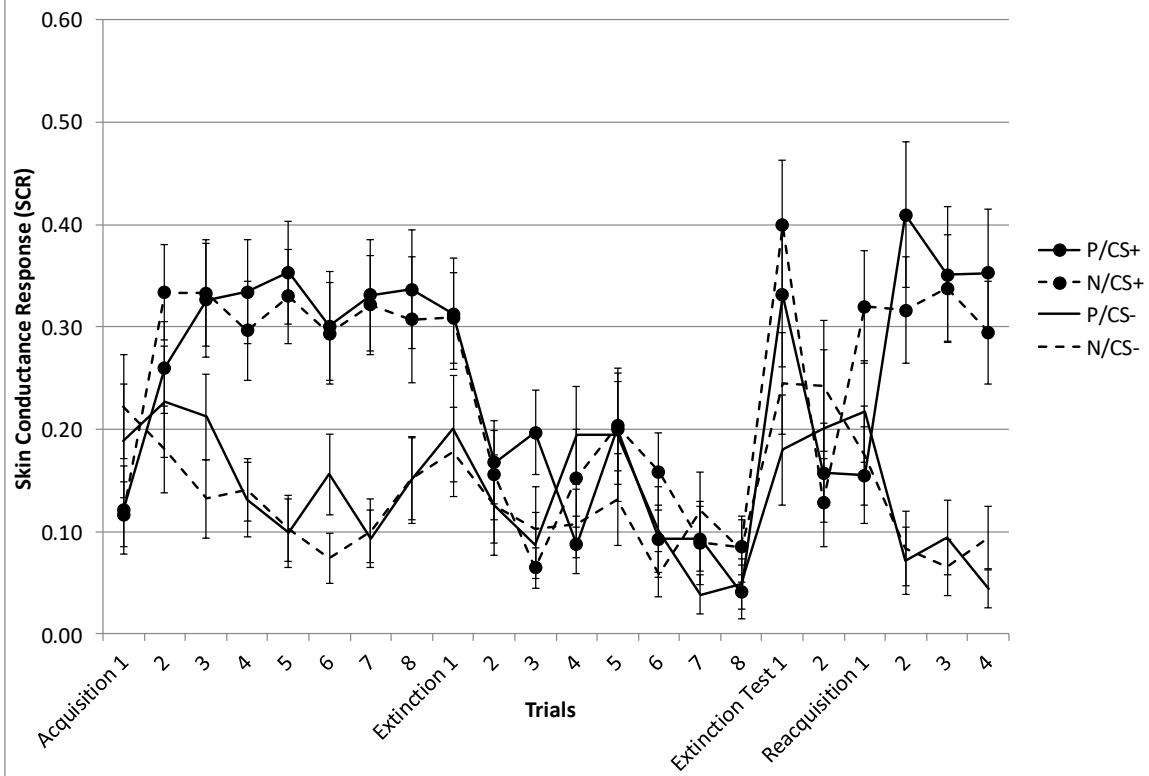
There were several limitations of the present study. First, as stated earlier, the negative videos were rated as more likely arousing than the positive videos, which may have enhanced inhibitory learning for individuals viewing the negative videos. Future studies would benefit

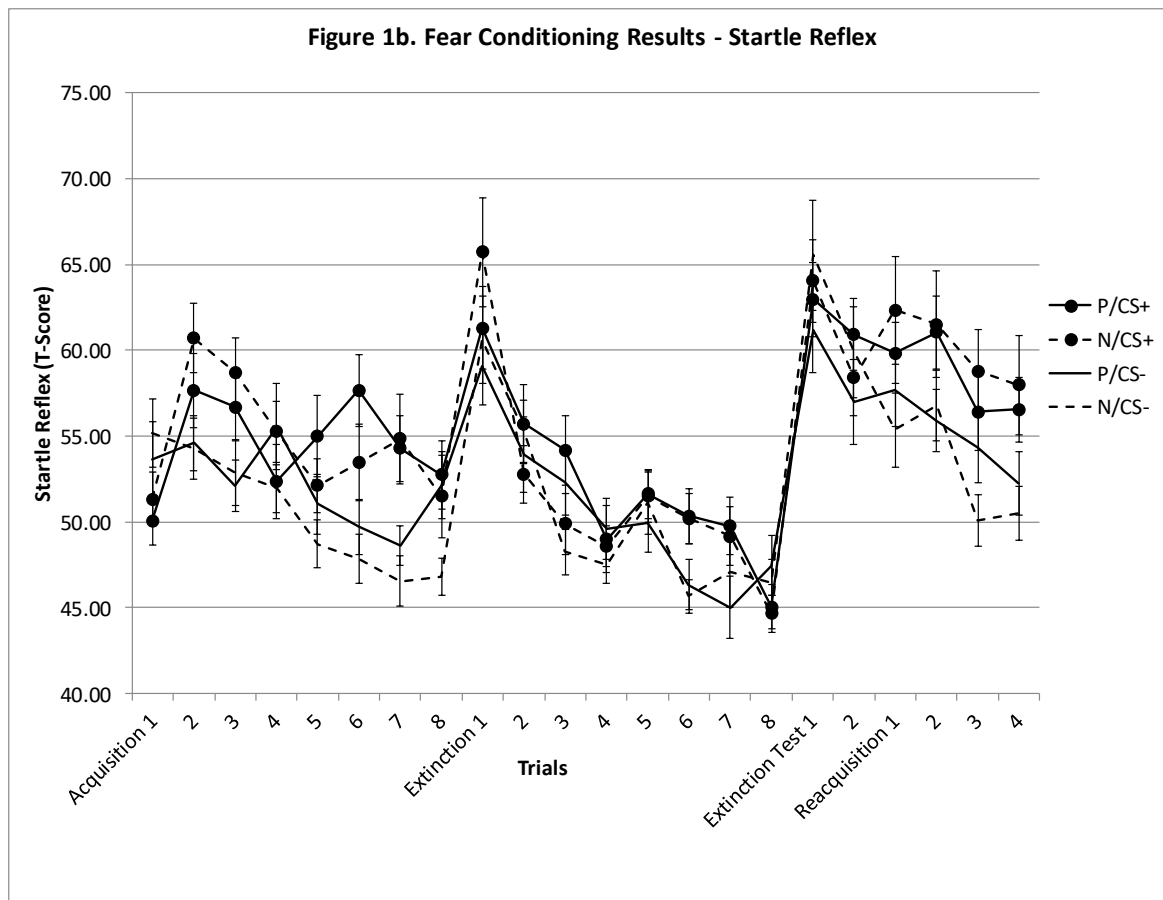
from mood inductions that are equated on arousal. Second, acquisition and extinction were conducted on the same day, which likely reduced excitatory learning and thus the fear observed one week later at test (Myers, Ressler & Davis, 2006). Additionally, the pre-extinction mood induction may also be considered a post-acquisition mood induction. Future studies would benefit from having acquisition on one day and extinction on a second day. Third, the findings model a one-week interval between extinction and test. It is unclear how these results would extend over longer periods of time or multiple sessions of extinction, which would be relevant for treatment of anxious individuals. Fourth, our measurement of positive and negative affect relied upon self-report. Our study would have been improved with a behavioral measure of affect, such as corrugator muscle movement (Larsen, Norris, & Cacioppo, 2003). Finally, generalizability of the findings to a clinically anxious sample await further investigation.

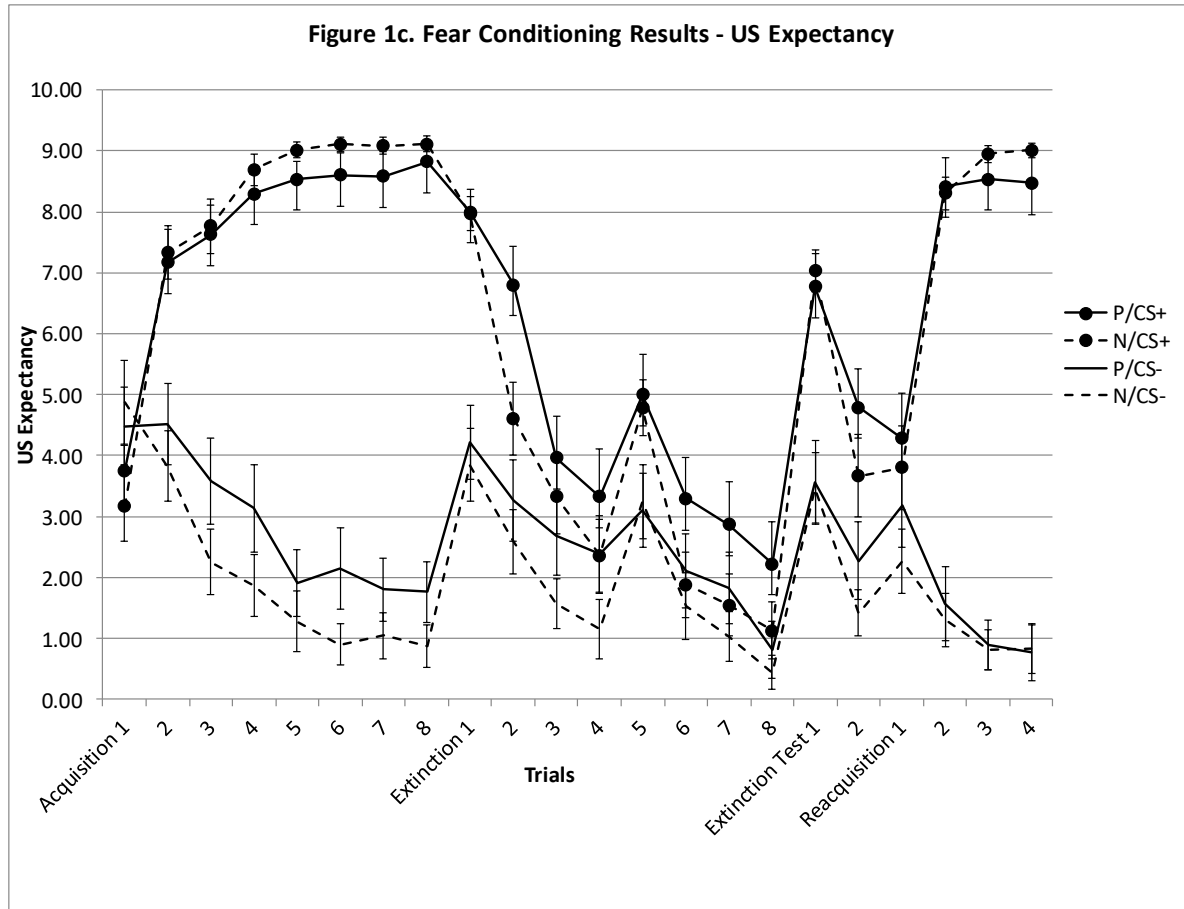
In conclusion, the present study suggests that manipulation of mood before and during extinction does not affect long-term extinction learning, spontaneous recovery, or reacquisition of fear. Our other work has shown that higher positive affect prior to extinction reduces reinstatement of conditional fear (Zbozinek, Holmes, & Craske, 2015), and higher positive affect before and after extinction predicts less reacquisition (Zbozinek & Craske, 2016). Thus, the evidence so far suggests that positive mood induction reduces reinstatement fear, may reduce reacquisition fear, but does not affect spontaneous recovery. Testing awaits for the relations between positive affect and renewal, as well as many other possible effects of positive affect on extinction learning (e.g., extinction generalization; Zbozinek & Craske, 2016). Clinical translation of the present study's findings would suggest that levels of positive and negative affect before an exposure therapy session would not affect return of fear when re-encountering

the previously feared object after a delay or if the previously feared object or situation is re-paired with aversive outcomes.

Figure 1a. Fear Conditioning Results - SCR







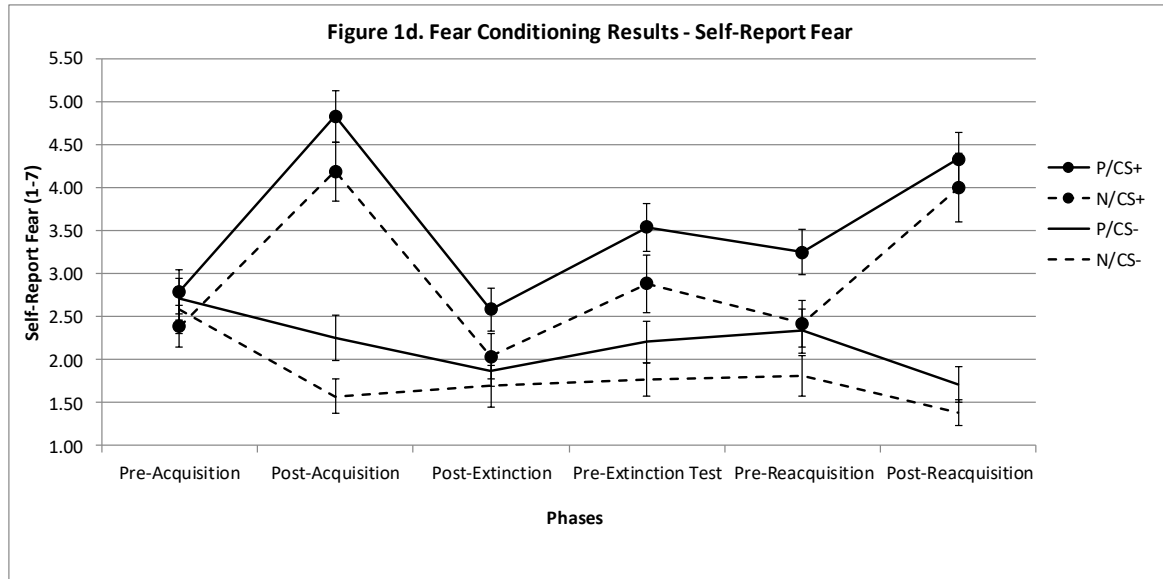


Figure 1.

a-d present fear conditioning data across acquisition, extinction, extinction test, and reacquisition for the CS+ and CS- with skin conductance response, startle reflex, unconditional stimulus (US) expectancy, and self-report fear collapsed across Mood Induction. Error bars are standard errors. "P" stands for positive mood induction; "N" stands for negative mood induction. Significant differential acquisition, was observed with all measures. US Expectancy was measured on a 0-9 scale, where 0 = "Certain no muscle stimulation", 4.5 = "Uncertain," and 9 = "Certain muscle stimulation." Self-report fear was measured on a 1-7 scale, where 1 = "Not at all fearful of" and 7 = "Very fearful of."

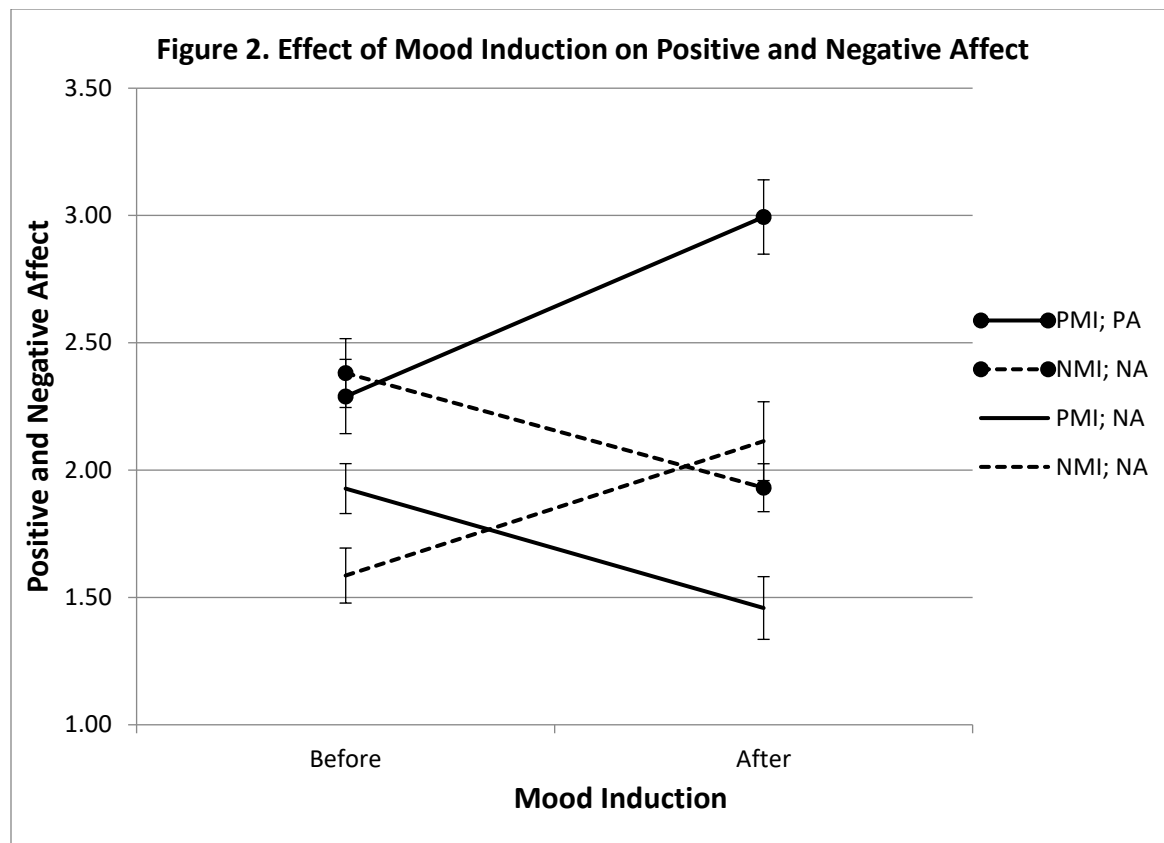


Figure 2

Presents the effects of mood induction on positive and negative affect before and after mood induction. Error bars are standard errors. “PMI” stands for positive mood induction; “NMI” stands for negative mood induction. “PA” stands for positive affect; “NA” stands for negative affect.

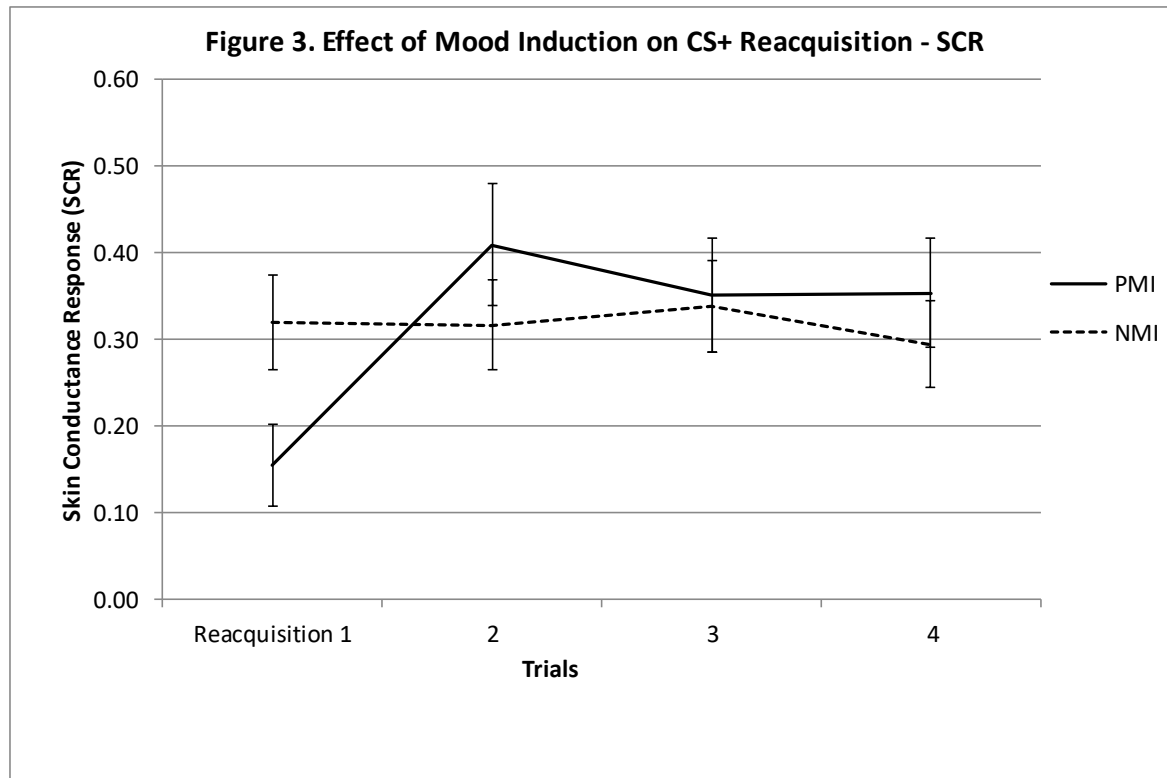


Figure 3

Presents the effects of mood induction on skin conductance response (SCR) for the CS+ during reacquisition. Error bars are standard errors. “PMI” stands for positive mood induction; “NMI” stands for negative mood induction. “PA” stands for positive affect; “NA” stands for negative affect. NMI had significantly higher SCR at the first reacquisition trial than PMI. There were no significant differences at the other trials. PMI also had a significantly higher slope than NMI.

Study 3: The Effects of Pre-Extinction Positive Mood Induction on Generalization of Extinction

Learning: Relevance for Exposure Therapy for Anxiety Disorders

Introduction

Exposure is well-established as an effective therapeutic strategy for anxiety disorders (Hofmann & Smits, 2008; In-Albon & Schneider, 2007), and processes of extinction learning considered to be key mechanisms of exposure therapy (Hermans, Craske, Mineka & Lovibond, 2006). In fear conditioning, a neutral stimulus is paired a number of times with the aversive unconditional stimulus (US; e.g., electric shock). Through these pairings, the neutral stimulus becomes a CS+ (i.e., a danger cue) and elicits a conditional fear response, whereas the CS that predicts the absence of the US is the CS- (i.e., a safety cue). Extinction is the procedure of presenting the CS+ in absence of the US, which results in lower fear responses to the CS+. Within inhibitory learning models, the original CS+/US association learned during acquisition of fear is not erased during extinction, but rather is left intact while a new, secondary CS+/NoUS inhibitory association develops (e.g., Bouton, 1993). Accordingly, two memories of the CS+ exist following extinction: one in which the CS+ predicts an aversive event and a separate memory in which the CS+ no longer predicts an aversive event.

Another feature of Pavlovian fear conditioning is fear generalization. An excitatory response gradient results in greater conditional fear to stimuli that are more similar to the CS+ compared to less similar stimuli (Guttman & Kalish, 1956; Hanson, 1959; Spence, 1936; Vervliet, et al., 2005; Vervliet, Vansteenwegen, & Eelen, 2004). Degree of fear generalization is operationalized by the steepness of the excitatory gradient with a flat slope indicating greater generalization. In the clinical context, an individual who is bitten (US) by a specific German shepherd dog (CS+) may generalize fear to generalization stimuli (GSs), such as other German shepherds, dogs of different breeds (e.g., Labradors), and even other animals (e.g., cats).

Individuals with anxiety disorders show enhanced fear generalization, as shown by flatter slopes following fear conditioning, than healthy controls (Lissek et al., 2009; Lissek et al., 2012; Lissek et al., 2014). Greater fear generalization is likely to contribute to the pervasiveness of phobias and anxiety disorders (Lissek et al., 2012). Fear generalization poses additional challenges for treatment, since exposure therapy is likely to target generalization stimuli rather than the original CS+ (i.e., other dogs versus the original dog that attacked) and also is unlikely to target all generalization stimuli, leaving the individual open to a return of fear. To this end, Vervliet et al. (2005) found that extinction of a GS reduced fear to that GS but no observable change in fear to the CS+. Furthermore, Vervliet, Vansteenwegen, and Eelen (2004) found that extinction to the CS+ reduced fear to the GS. These findings point to the value of conducting exposure therapy with the original CS+ (assuming the CS+ is not actually dangerous) for fear reduction to the CS+ as well as generalizing fear reduction to GSs. However, it is often difficult and sometimes impossible to conduct exposure to the CS+ itself due to logistical reasons, and hence most exposures are conducted using GSs. Thus, methods for generalizing extinction learning to generalization stimuli are becoming increasingly recognized as essential targets.

Variability during motoric and verbal learning trials has been shown to strengthen learning and later performance (Bjork & Bjork, 1992; Kerr & Booth, 1978; Smith, Glenberg, & Bjork, 1978; Schmidt & Bjork, 1992). From an associative learning theory perspective, increased GS variability during extinction or exposure may enhance generalization of extinction since variability is more likely to characterize contexts in which phobic stimuli are encountered once exposure therapy is complete and thereby offset context renewal effects. Variability has been demonstrated in anxious samples such that variability in timing between exposures (Rowe & Craske, 1998; Tsao & Craske, 2000) and variability of stimuli during exposures (Lang &

Craske, 2000; Rowe & Craske, 1998) improved outcomes for specific phobias, although an additional study of contaminant anxiety showed only trends (Kircanski, et al., 2012). These findings suggest that variability during extinction, by using a variety of GSs, may facilitate generalization of extinction learning.

From the positive affect literature, higher positive affect enhances semantic processing (e.g., Clore & Huntsinger, 2007). With relevance specifically to the present study, individuals in a positive mood are better able to learn rules to categorize information than individuals in negative or neutral moods (Nadler, et al., 2010). Also, PA can generate false memory as a function of enhanced semantic processing during encoding. Storbeck and Clore (2005) found that individuals in a positive mood were more likely to falsely remember having seen critical lures in a word list than individuals in a negative mood. For example, a list of words may include *bed, pillow, rest, awake, and dream*. By activating a semantic network of related words and concepts, individuals may later believe they saw the word *sleep* (i.e., the critical lure) even though it was not presented. By engaging in more semantic processing, individuals with greater positive mood are more likely to activate the non-presented word *sleep* during encoding. At the time of retrieval, they might remember thinking about the word *sleep* but misattribute it to being part of the word list (e.g., thinking they saw the word *sleep*). Storbeck and Clore (2005) demonstrated that the critical period for the false memory effect was during encoding, not during retrieval. This may have important consequences for extinction learning and, by proxy, exposure therapy. For example, positive mood may lead to the mistaken memory that certain types of dogs were approached during exposure therapy when in fact they were not and lead to less fear when those same dogs are later encountered. Hence, PA may enhance the generalization of extinction and thereby exposure therapy.

In the present study, we aimed to test the effects of PA on false memory, categorical rule generation, and extinction learning. We hypothesized that positive mood during extinction with a variety of GSs within a specific semantic category (e.g., colors) would lead to less fear of a novel GS at test. This was hypothesized because positive mood would increase false memory of a semantically representative color that was not actually present during extinction (e.g., blue), thus leading to less fear of a novel GS, relative to negative mood. This would be evidenced by less fear of a novel GS at test, mediated through false memory of having viewed that GS during extinction. Second, we hypothesized that positive mood during extinction would reduce fear of the extinction GSs at test. This was hypothesized because positive mood would increase semantic processing, which could enhance encoding during extinction. Also, positive mood is associated with enhanced categorization of information relative to negative mood; positive mood may enhance categorization that all colors are now safe, or all colors *except* the CS+ are now safe. Third, we hypothesized that positive mood would be associated with less fear of the CS+ at test if indeed participants in a positive mood developed a stronger categorization that all colors including the CS+ are safe.

Methods

Participants

Participants (N = 109) were students from the University of California, Los Angeles, who participated for course credit. Four participants dropped out partway through the study, leaving 105 participants completers. Participants were 72.8% female; mean age 21.600 (SD = 2.973) years; and 3.5% African-American, 38.6% Asian or Asian-American, 21.9% Caucasian, 28.1% Hispanic/Latino, 0.9% Native Hawaiian or Other Pacific Islander, 2.6% Middle Eastern, and 4.4% Multiracial. This study was approved by the University of California, Los Angeles

Institutional Review Board, and all participants provided informed consent prior to commencing the study.

Design

Participants underwent habituation, acquisition, mood induction, and extinction on Day 1. One week later (i.e., Day 8), participants conducted a test phase. CS Type (CS+, CS-, GS) and Trials were within-subject factors. Mood Induction (Positive, Negative) was the between-subjects factor.

Materials and Apparatus

CS and US

The Pavlovian conditioning procedure was programmed using E-Prime 2 Professional Version 2.0.10.353. The CSs and GSs were chosen from two validated semantic categories that were qualitatively different from each other: color and kitchen utensils (Battig & Montague, 1969). The items were rank-ordered in terms of their representativeness of the semantic category (Battig & Montague, 1969). In order of most to least semantically representative, the colors were blue, red, green, yellow, orange, black, purple, white, pink, brown, and gold.¹ For the kitchen utensils category, the order of most to least semantically representative items used were knife, spoon, fork, pan, pot, stove, bowl, cup, refrigerator, glass, toaster. We used drawings developed by Snodgrass and Vanderwart (1980) of the top 12 most semantically representative items from the Battig and Montague (1969) set. The third-most semantically representative item from each category (i.e., green triangle and fork) was used as the CS+ and CS-, counterbalanced. We reserved the most semantically representative item as the novel GS at test, which is consistent

¹ Violet and turquoise were ranked above gold in Battig and Montague (1969), but we did not include them because they were similar to purple and blue, respectively. Also, we did not use gray because our inter-trial intervals (ITIs) were gray.

with the false memory literature (Storbeck & Clore, 2005). The remaining stimuli were used during extinction. Thus, the acquisition CS+ differed from the extinction GSs, and the novel GS at test was not present during either acquisition or extinction. At test, we presented the CS+, CS-, novel GS, and the semantically central GS from extinction (i.e., purple, bowl) and measured SCR, startle reflex, and US expectancy during trial presentations. For self-report fear at test, we measured the CS+, CS-, novel GS, and *all* nine extinction GSs, as self-report fear was measured after presentations of the test trials.

The CSs were displayed on a 21-inch computer monitor for 8 seconds located three feet from the participants at eye level. The CSs were 525 x 525 pixels, which covered most of the center of the screen. The CSs were pseudo-randomized with no more than two consecutive presentations of the CS+, CS-, or GS in a given phase. Prior to acquisition, the CS+ and CS- were presented twice to reduce novelty and responding (i.e., habituation). Inter-trial intervals (ITIs) were randomized to either 25 or 35 seconds and involved a gray screen with a small black fixation cross in the center. An electric shock US was delivered to the dominant arm bicep using the STMEPM, two LEAD110A (BIOPAC, Inc.), and two Telectrode T716 Ag/AgCl electrodes. The shock consisted of 10 consecutive pulses .05 seconds in duration, totaling .5 seconds. The CS+/US reinforcement rate during acquisition was 100%; participants received seven shocks during acquisition, with an onset 7.5 seconds after CS+ onset and co-terminating with the CS+. US intensity was determined using a work-up procedure (see Procedures).

Mood Induction

Mood induction consisted of 12 commercial videos (six positive and six negative) ranging from 30 to 80 seconds each. The Positive videos totaled 4 minutes 40 seconds, and the Negative videos totaled 4 minutes 49 seconds. The six Positive videos were high in positive

valence (e.g., humorous car commercials), and the six Negative videos were low in positive valence (e.g., anti-domestic violence commercials). As part of a larger study (Paulus et al., in preparation), the commercials were rated by 29 individuals for valence and arousal in a within-subjects design using the self-assessment manikin (SAM; Bradley & Lang, 1994) on 1-9 scales, where 1 = “unhappy” and 9 = “happy” on the valence scale, and 1 = “calm” and 9 = “excited” on the arousal scale. Using a 2 (Video Valence: Positive, Negative) x 6 (Video Number) repeated measures ANOVA, the Positive videos ($M = 7.575$, $SD = .862$) were rated as significantly more positive than the Negative commercials ($M = 2.454$, $SD = .878$) ($F(1,28) = 385.995$, $p < .001$, $\eta_p^2 = .932$). The videos did not differ in ratings of arousal: Positive ($M = 4.304$, $SD = 1.789$) and Negative commercials ($M = 4.560$, $SD = 1.704$) ($F(1,27) = .618$, $p = .438$).

Measures of Fear

US expectancy. To test explicit associative learning, participants were asked to “Please rate how certain you are that you will receive electric shock in the next few moments” while reminder prompts appeared at the bottom of the screen; the prompt (“Electric Shock?”) was present during the first eight seconds of each ITI and CS. The values ranged from 0 = “Certain no electric shock”, 4.5 = “Uncertain,” and 9 = “Certain electric shock.” US expectancy was calculated as the mean rating 6.5-7 seconds after CS and ITI onset.

Self-Report Fear. When presented with a small image of the CS in the top-left corner of the computer screen, participants rated “how fearful this image makes you feel” using a 1-7 scale, where 1 = “Not at all fearful”, 4 = “Moderately fearful,” and 7 = “Very fearful.” Images terminated upon completion of the fear rating. Self-report fear was measured before and after acquisition and after test. Before acquisition, participants rated fear for the CS+ and CS-. After test, participants rated fear for the CS+, CS-, and all 10 GSs presented in the study. Self-report

fear ratings were not obtained after extinction so as to not remind participants which GSs they saw during extinction. This is consistent with the false memory literature, in which the learning material is typically presented only once before test (Storbeck & Clore, 2005).

BIOPAC MP150 hardware unit and AcqKnowledge version 4.2 software (BIOPAC Systems, Inc.) were used to acquire all physiological data.

Skin conductance response (SCR). SCRs were recorded as a measure of arousal from two EL507 11mm diameter Ag/AgCl electrodes placed on the distal phalanx of the index and middle fingers of the non-dominant hand (e.g., Bradley, Cuthbert, & Lang, 1990). Using a GSR100C amplifier and two LEAD110A, SCR data were sampled at a rate of 31.25 Hz and filtered using an FIR low pass filter with a frequency cutoff fixed at 2Hz. SCR was calculated as a difference score between the maximum skin conductance value 1 to 6 seconds after CS or US onset minus the mean skin conductance value of the 2 seconds prior to CS or US onset.

Startle Reflex. The startle reflex was measured with electromyography (EMG) orbicularis oculi activity under the left eye using two EL254S 4mm Ag/AgCl electrodes filled with SignaGel electrode gel measured with the EMG100C amplifier. Electrode placement was 1cm beneath the outer corner of the eye. The second electrode was placed 1cm medial to the first electrode and 1cm beneath the bottom eyelid so the pair of electrodes run parallel to the bottom eyelid (Fridlund & Cacioppo, 1986). The startle probes (i.e., acoustic startle stimuli delivered to elicit eye blink startle reflexes) consisted of 50 milliseconds, 102 dB bursts of “white noise” with an instantaneous rise time delivered binaurally through stereophonic headphones. Startle probes occurred 7 seconds after CS onset and were randomized to occur 10, 15, or 25 seconds after onset of the inter-trial interval (i.e., ITI), averaging at 16.25 seconds. Habituation prior to acquisition (Day 1) and extinction test (Day 8) consisted of 10 startle probes across a 2.5-minute

period during a blank white screen. EMG data were sampled at a rate of 2kHz. The data were filtered using an FIR band pass filter with a low frequency cutoff of 60Hz and a high frequency cutoff of 500Hz. Data were then converted to an absolute value and smoothed using .005 samples mean value smoothing. Startle reflex was calculated as the difference between the absolute maximum EMG level in volts during the 20ms-150ms immediately after the startle probe and the mean EMG level in volts during the 200ms immediately preceding the startle probe. EMG data were then transformed into a within-subjects t-score using responses to all CSs and ITIs across both days (startle habituation trials were excluded from t-score calculations).

Measures of Affect

Positive and Negative Affect Schedule (PANAS; Watson & Clark, 1994; Watson, Clark, & Tellegen, 1988). Participants completed the PANAS before habituation, before and after mood induction, after extinction, and prior to test to measure state PA and NA: “right now (that is, in the present moment).” Our measure of PA included a composite score of the Joviality, Self-Assurance, and Attentiveness subscales. The measure of NA was the general NA scale. In the present study, Cronbach’s α was .962 for PA and .899 for NA.

Measures of Memory

Recall. Immediately after completing the test phase on Day 8, participants were asked to recall the CSs and GSs they saw on Day 1: “Type in the box below, and list all of the [DRAWINGS, COLORS of the TRIANGLES] you saw last week at your PREVIOUS APPOINTMENT.” 1 point was assigned for every correct response (range = 0-11).

Recognition. Immediately after completing the test of recall on Day 8, participants were sequentially shown each CS and GS from Day 1 (12 total), as well as six decoy GSs that had never been shown in a pre-determined randomized order. Participants indicated whether they had

seen “this image” before (yes/no). One point was assigned for each correct identification (range 0-12). Zero points were assigned for each decoy GS indicated as having not been seen and one point was lost for each decoy GS indicated as having been seen. Thus, the scores for errors of commission ranged from -6 to 0. These two scores were summed to provide a total recognition accuracy score, which ranged from -6 to 12.

Procedure

The experiment consisted of two assessments one week apart (i.e., Day 1 and Day 8). On Day 1, participants provided informed consent, physiological equipment was attached, and a shock workup procedure was conducted. Shocks started at a low intensity and increased to the level a participant considered “uncomfortable but not painful” ($M = 6.345$, $SD = .997$) using a 0-10 discomfort scale (0 = “Not at all,” 5 = “Moderately,” and 10 = “Very”). Participants were then trained to use the US expectancy dial. The primary experimental phases occurred in the following sequence: startle habituation (10 startle probes during an ITI), habituation (2 CS+ and 2 CS-), self-report fear ratings (CS+ and CS-), acquisition (7 CS+/US and 7 CS-), self-report fear ratings (CS+ and CS-), mood ratings, mood induction (6 videos), mood ratings, extinction (nine CS- and one trial for each of the nine GSs besides the critical lure GS), and mood ratings. To be consistent with the false memory literature (Storbeck & Clore, 2005), we presented each of the GSs in order from most semantically representative to least semantically representative during extinction.

On Day 8, after physiological equipment was attached and participants were reminded how to use the US expectancy dial, procedures included startle habituation (10 startle probes during an ITI), test phase (novel GS, CS-, CS+, extinction GS), recall test, recognition test, and self-report fear measurement. During the test phase, the order for the novel GS and CS-, and the

order between the GS that was semantically central from extinction (i.e., purple triangle or bowl) and the CS+, were randomized.

Data Analysis

We used STATA 14.2 to conduct multilevel modeling for habituation, acquisition, mood induction, and extinction (Bryk & Raudenbush, 1992), as has been used in prior fear conditioning studies (e.g., Gazendam et al., 2015; Pineles, Vogt, & Orr, 2009; Zbozinek & Craske, 2017). The linear slope indicates the rate of change in values across repeated measures, and the quadratic slope indicates change in linear slope across repeated measures (i.e., acceleration/deceleration of linear slope). Tests of acquisition and extinction involved multilevel models with repeated measures as a level 1 factor and individuals as a level 2 factor. Level 1 predictors included CS Type (CS+, CS-, extinction GSs), Linear Slope (Trial 1, Trial 2, etc.), and Quadratic Slope (Trial 1, Trial 2, etc.). In the absence of repeated measures across trials during the extinction test phase, slopes were not included in the analyses. We additionally conducted separate analyses based on qualitative differences in the CSs at test. The CS+ and CS- were analyzed together, the extinction GSs were analyzed together, and the novel GS was analyzed alone. Mood Induction (Positive, Negative) was a level 2 predictor for all analyses. Dependent variables were SCR, startle reflex, US expectancy, and self-report fear, and SAM valence, PA, and NA were measures of mood.

Results

Acquisition

See Figures 1a-d for fear during habituation, acquisition, and extinction. For SCR, there was a significant CS Type (CS+, CS-) x Linear Slope (Trials 1-7) interaction ($\chi^2(1) = 24.76$, $p < .001$) with a significantly steeper incline for the CS+ than the CS- ($Z = 4.96$, $p < .001$). The CS+

had a significant positive linear slope ($Z = 5.43, p < .001$), but the CS- linear slope did not significantly differ from zero ($Z = -1.59, p = .111$). There was also a significant CS Type (CS+, CS-) x Linear Slope (Trials 1-7) x Quadratic Slope (Trials 1-7) interaction ($\chi^2(1) = 12.04, p < .001$) with greater deceleration for the CS+ than the CS- (i.e., the CS+ approached a maximum asymptote; $Z = -2.60, p = .009$). The CS+ had significant deceleration in slope ($Z = -3.23, p = .001$), but the quadratic slope for the CS- did not significantly differ from zero ($Z = 0.44, p = .658$). Thus, we observed differential fear acquisition for SCR driven by an increase in CS+ and no change in CS- SCR. There were no significant effects involving Mood Induction ($ps > .211$).

For startle reflex, there was a significant CS Type (CS+, CS-) x Linear Slope (Trials 1-7) interaction ($\chi^2(1) = 17.17, p < .001$) with a significantly steeper incline for the CS+ than the CS- ($Z = 4.13, p < .001$). The CS+ had a significant positive linear slope ($Z = 2.73, p = .006$), whereas the CS- had a significantly negative linear slope ($Z = -3.12, p = .002$). There was also a significant CS Type (CS+, CS-) x Linear Slope (Trials 1-7) x Quadratic Slope (Trials 1-7) interaction ($\chi^2(1) = 8.70, p = .003$) with greater deceleration for the CS+ than the CS- (i.e., the CS+ approached a maximum asymptote; $Z = 2.37, p = .018$). The CS+ had significant deceleration in slope ($Z = -2.44, p = .015$), whereas the quadratic slope for the CS- did not significantly differ from zero ($Z = 0.91, p = .361$). Thus, we observed differential fear acquisition for startle reflex driven by an increase in CS+ and a decrease in CS- startle reflex. There were no significant effects involving Mood Induction ($ps > .630$).

For US expectancy, there was a significant CS Type (CS+, CS-) x Linear Slope (Trials 1-7) interaction ($\chi^2(1) = 221.42, p < .001$) with a significantly steeper incline for the CS+ than the CS- ($Z = 14.93, p < .001$). The CS+ had a significant positive linear slope ($Z = 14.70, p < .001$), whereas the CS- had a significantly negative linear slope ($Z = -6.40, p < .001$). There was also a

significant CS Type (CS+, CS-) x Linear Slope (Trials 1-7) x Quadratic Slope (Trials 1-7) interaction ($\chi^2(1) = 79.95, p < .001$) with greater deceleration for the CS+ than the CS- (i.e., the CS+ approached a maximum asymptote; $Z = 5.94, p < .001$). The CS+ had significant deceleration in slope ($Z = -6.79, p < .001$), whereas the quadratic slope for the CS- did not significantly differ from zero ($Z = 1.60, p = .109$). Thus, we observed differential fear acquisition for US expectancy driven by an increase in CS+ and a decrease in CS- US expectancy. There were no significant effects involving Mood Induction ($ps > .151$).

For self-report fear, there was a significant CS Type (CS+, CS-) x Linear Slope (before acquisition, after acquisition) interaction ($\chi^2(1) = 184.89, p < .001$) with a significantly steeper incline for the CS+ than the CS- ($Z = 13.76, p < .001$). The CS+ had a significant positive linear slope ($Z = 13.20, p < .001$), whereas the CS- had a significantly negative linear slope ($Z = -6.26, p < .001$). There were no significant effects involving Mood Induction ($ps > .112$).

Mood Induction

See Figure 2 for the effects of Mood Induction on PA and NA. For PA, there was a significant Mood Induction (Positive, Negative) x Time (before mood induction, after mood induction, after extinction) interaction ($\chi^2(1) = 84.23, p < .001$). Simple effects showed no significant difference in PA between the positive and negative mood groups before mood induction ($Z = -0.26, p = .795$) or after extinction ($Z = 0.32, p = .748$), but there was significantly greater PA in the positive group than the negative group after mood induction ($Z = 5.59, p < .001$). Additionally, the positive group significantly increased PA from before to after mood induction ($Z = 6.69, p < .001$), significantly decreased from after mood induction to after extinction ($Z = -10.37, p < .001$). Conversely, the negative group significantly decreased PA from before to after mood induction ($Z = -5.13, p < .001$). However, there were no significant

differences when comparing after mood induction to after extinction ($Z = 0.47$, $p = .638$). In sum, the mood induction successfully manipulated PA after mood induction, though the groups no longer differed by the end of extinction.

For NA, there was a significant Mood Induction (Positive, Negative) x Time (before mood induction, after mood induction, after extinction) interaction ($\chi^2(1) = 62.15$, $p < .001$). Simple effects showed that there was no significant difference in NA between the positive and negative mood groups before mood induction ($Z = -1.69$, $p = .090$), but there was significantly less NA in the positive group than the negative group after mood induction ($Z = -7.00$, $p < .001$) and after extinction ($Z = -2.00$, $p = .046$). However, the difference in NA between the positive and negative groups was significantly greater after mood induction than after extinction ($Z = 6.62$, $p < .001$). Additionally, the positive group significantly decreased NA from before to after mood induction ($Z = -7.11$, $p < .001$) and significantly increased from after mood induction to after extinction ($Z = 2.54$, $p = .011$). Conversely, the negative group significantly increased NA from before to after mood induction ($Z = 2.91$, $p = .004$), significantly decreased from after mood induction to after extinction ($Z = -4.75$, $p < .001$). In sum, the mood induction successfully manipulated NA after mood induction and after extinction.

Extinction

See Figures 1a-d for fear during acquisition and extinction. For SCR, there were no significant effects involving Mood Induction ($ps > .116$). There was a significant CS Type (GS 1-9, CS-) x Linear Slope (Trials 1-9) interaction ($\chi^2(1) = 6.36$, $p = .012$) with a significantly steeper decline for the GSs than the CS- ($Z = 2.44$, $p = .015$). The GSs had a significant negative linear slope ($Z = -4.59$, $p < .001$), but the CS- linear slope did not significantly differ from zero ($Z = -1.14$, $p = .255$). There was also a significant CS Type (GS 1-9, CS-) x Linear Slope (Trials

1-9) x Quadratic Slope (Trials 1-9) interaction ($\chi^2(1) = 5.06$, $p = .025$) with greater acceleration for the GSs than the CS- (i.e., the GSs approached a minimum asymptote; $Z = -2.49$, $p = .013$). The GSs had significant acceleration in slope ($Z = 3.87$, $p < .001$), but the quadratic slope for the CS- did not significantly differ from zero ($Z = 0.34$, $p = .731$). Thus, we observed differential fear extinction for SCR driven by a decrease in GS and no change in CS- SCR.

For startle reflex, there were no significant effects involving Mood Induction ($ps > .194$). Nor was there a significant CS Type (GS 1-9, CS-) x Linear Slope (Trials 1-9) interaction ($\chi^2(1) = 0.01$, $p = .939$) or a significant CS Type (GS 1-9, CS-) x Linear Slope (Trials 1-9) x Quadratic Slope (Trials 1-9) interaction ($\chi^2(1) = 0.18$, $p = .673$). There were, however, main effects of Linear Slope ($Z = -10.86$, $p < .001$), Quadratic Slope ($Z = 7.27$, $p < .001$), and CS Type ($Z = 3.20$, $p = .001$). The main effects indicated a negative linear slope, positive acceleration, and greater startle reflex for the GSs than the CS-. Thus, we observed a non-differential decrease in startle reflex across the GSs and CS- while maintaining greater startle reflex to the GSs than the CS- across trials.

For US expectancy, there were no significant effects involving Mood Induction ($ps > .211$). Nor was there a significant CS Type (GS 1-9, CS-) x Linear Slope (Trials 1-9) interaction ($\chi^2(1) = 2.97$, $p = .085$). However, there was a significant main effect of Linear Slope ($Z = -7.93$, $p < .001$) with a decrease in US expectancy across trials. There was also a significant CS Type (GS 1-9, CS-) x Linear Slope (Trials 1-9) x Quadratic Slope (Trials 1-9) interaction ($\chi^2(1) = 10.22$, $p = .001$), although the simple effects showed that no significant difference in Quadratic Slope between the GSs and CS- ($Z = 1.35$, $p = .178$). There was additionally a significant main effect of CS Type ($Z = -14.56$, $p < .001$) with greater US expectancy for the GSs than the CS-.

Thus, we observed a non-differential decrease in US expectancy across the GSs and CS- while maintaining greater US expectancy to the GSs than the CS- across trials.

Extinction Test – CS+ and CS-

See Figures 3a-d for fear at extinction test. We used a Mood Induction (Positive, Negative) x CS Type (CS+, CS-) x Linear Slope (End of Acquisition, Test) mixed model.

For SCR, there were no significant effects involving Mood Induction ($ps > .294$). Additionally, there was no significant interaction between CS Type and Linear Slope ($\chi^2(1) = 1.16, p = .281$). However, there was a main effect of CS Type with greater fear to the CS+ than the CS- ($\chi^2(1) = 23.30, p < .001$) and a main effect of Linear Slope with an increase in fear from the end of acquisition to test ($\chi^2(1) = 16.95, p < .001$).

For startle reflex, there were no significant effects involving Mood Induction ($ps > .311$). Additionally, there was no significant interaction between CS Type and Linear Slope ($\chi^2(1) = 0.91, p = .340$). However, there was a main effect of CS Type with greater fear to the CS+ than the CS- ($\chi^2(1) = 14.25, p < .001$) and a main effect of Linear Slope with an increase in fear from the end of acquisition to test ($\chi^2(1) = 33.86, p < .001$).

For US expectancy, there were no significant effects involving Mood Induction ($ps > .153$). However, there was a significant interaction between CS Type and Linear Slope ($\chi^2(1) = 48.76, p < .001$). Simple effects showed that there was a significant decrease in US expectancy for the CS+ ($Z = -5.21, p < .001$) and a significant increase for the CS- ($Z = 4.68, p < .001$). The slope for the CS+ was significantly lower than the slope for the CS- ($Z = 6.99, p < .001$). Additionally, there was significantly greater US expectancy for the CS+ than the CS- at the end of acquisition ($Z = 26.07, p < .001$) and at test ($Z = 15.49, p < .001$).

For self-report fear, there were no significant effects involving Mood Induction (p s > .202). Additionally, there was no significant interaction between CS Type and Linear Slope ($\chi^2(1) = 1.41, p = .235$). There was also no significant main effect of Linear Slope ($\chi^2(1) = 2.42, p = .120$). However, there was a main effect of CS Type with greater fear to the CS+ than the CS- ($\chi^2(1) = 233.98, p < .001$).

Extinction Test – GS(s) from Extinction

There was no significant main effect of Mood Induction for the extinction GS with SCR ($\chi^2(1) = 0.39, p = .532$) ($M = .134, SD = .193$), startle reflex ($\chi^2(1) = 1.01, p = .316$) ($M = 51.969, SD = 10.642$), or US expectancy ($\chi^2(1) = 0.48, p = .486$) ($M = 3.120, SD = 2.832$). Similarly, for self-report fear, there were no significant effects involving Mood Induction (p s > .182) for the nine extinction GSs.

Extinction Test – Novel GS

There was no significant main effect of Mood Induction for the novel GS with SCR ($\chi^2(1) = 0.00, p = .992$) ($M = .134, SD = .193$), startle reflex ($\chi^2(1) = 0.12, p = .731$) ($M = 51.969, SD = 10.642$), or US expectancy ($\chi^2(1) = 1.89, p = .169$) ($M = 3.120, SD = 2.832$) as measures. However, for self-report fear, there was a significant main effect of Mood Induction (Positive, Negative) ($\chi^2(1) = 4.41, p = .036$) with less fear in the positive ($M = 1.692, SD = 1.094$) than the negative group ($M = 2.250, SD = 1.595$).

Memory - Recall

See Figure 4 for recall of the CS+ and GSs across Mood Induction. There were no significant effects involving Mood Induction for total recall of the CS+ and GSs together ($\chi^2(1) =$

3.27, $p = .071$), the CS+ alone ($\chi^2(1) = 0.00$, $p = .989$), the extinction GSs, ($ps > .053$), or the novel GS alone ($\chi^2(1) = 0.02$, $p = .891$).

Memory - Recognition

See Figure 5 for recognition of all CSs and GSs across Mood Induction. There were no significant effects involving Mood Induction in predicting the total recognition accuracy score across all CSs and GSs ($\chi^2(1) = 0.03$, $p = .867$), the CS+ ($\chi^2(1) = 1.00$, $p = .317$), the extinction GSs ($ps > .313$), or the novel GS ($\chi^2(1) = 1.03$, $p = .310$).

Discussion

The present study evaluated the effects of pre-extinction mood induction on extinction with a variety of generalization stimuli that were from the same semantic category as the original conditional stimulus that predicted the electric shock aversive event. These effects were tested one week after extinction to the original conditional stimulus that was paired with shock, a generalization stimulus from extinction, a novel generalization stimulus, and the conditional stimulus that was never paired with shock. The primary study hypothesis was that induced positive affect would lessen fear relative to a reduced positive affect across various indices of fear, including skin conductance arousal, startle reflex, expectancy for the aversive event, and self-report fear. Specifically, we predicted positive mood induction would reduce fear to the novel generalization stimulus, the extinction generalization stimulus, and possibly the original conditional stimulus. The results did not support the hypotheses of fear reduction to the extinction generalization stimulus nor the original conditional stimulus but modestly supported the hypothesis with the novel generalization stimulus.

Viewing positive commercials successfully increased positive affect and reduced negative affect relative to viewing more negative commercials. There were no significant effects of mood induction on any measure of fear for the original conditional stimulus nor the extinction generalization stimulus. For the novel generalization stimulus, there were no significant effects involving skin conductance arousal, startle reflex, or expectancy for the aversive event. However, there was reduced fear towards the novel generalization stimulus for the positive mood group compared to the negative mood group as measured by self-report fear. The hypothesized pathway of the effect of mood induction on novel generalization stimulus fear included increased false memory as the mediator. However, mood induction did not significantly predict recall nor recognition of the novel generalization stimulus, so this pathway was unsupported.

In translation to the clinical context of exposure therapy, the findings suggest that individuals in a positive mood before exposure will have less self-report fear of a novel generalization stimulus if exposure is conducted with a variety of generalization stimuli. Importantly, the effect of mood induction occurred on a stimulus that had not undergone extinction, suggesting positive mood induction may be a method of generalizing extinction learning to novel stimuli and reducing self-report fear. For example, individuals with fear of public speaking would experience less self-report fear upon giving a speech with a new audience (novel generalization stimulus) after completion of exposures in a positive mood with a variety of other audiences.

Our hypotheses were based on prior evidence for positive affect to enhance semantic encoding (Brand, et al., 2007; Craik, 2002; Craik & Lockhart, 1972; Kiefer, et al., 2007; Lee & Sternthal, 1999), which is associated with improved long-term memory (Craik, 2002; Craik & Lockhart, 1972). We have hypothesized that positive affect may enhance the encoding, rehearsal,

and retrieval of extinction learning (Zbozinek & Craske, in press). Furthermore, positive affect may facilitate the integration of incoming inhibitory learning with already-existing excitatory learning via relational processing (Storbeck & Clore, 2007), such that greater activation of the inhibitory association occurs when the excitatory association is activated at a later time, which presumably occurs during test. These would suggest that positive affect would enhance extinction learning to the generalization stimuli present during extinction. However, we did not observe this effect.

Furthermore, previous studies have shown that, because positive affect increases semantic processing, it can produce a false memory effect for unrepresented items in a semantic category. Storbeck and Clore (2005) found that individuals in a positive mood were more likely to falsely remember having seen critical lures in a word list than individuals in a negative mood. For example, a list of words may include *bed*, *pillow*, *rest*, *awake*, and *dream*. By activating a semantic network of related words and concepts, individuals may later believe they saw the word *sleep* (i.e., the critical lure) even though it was not presented. By engaging in more semantic processing, individuals with greater positive mood are more likely to activate the non-presented word *sleep* during encoding. At the time of retrieval, they might remember thinking about the word *sleep* but misattribute it to being part of the word list (e.g., thinking they saw the word *sleep*). We observed reduced self-report fear of the “critical lure” novel generalization at test in the positive mood group. However, positive mood did not predict false memory of the generalization stimulus, so the purported mechanism was not supported in this study. Importantly, though, memory for the various stimuli was tested *after* presenting the stimuli to test fear, so participants had already seen the novel generalization stimulus prior to testing memory for it, which is inconsistent with the false memory literature. Thus, our ability to detect

any potential effects of mood induction on memory was likely compromised by presenting the stimuli a few minutes prior. We made this decision due to potential interference of the recall and recognition test with extinction test. We prioritized the fear conditioning literature over the false memory literature, thus limiting our test for memory.

Moreover, positive mood has been shown to enhance categorization of information (Nadler, et al., 2010). We hypothesized the positive group would enhance categorization that all stimuli are safe, or all generalization stimuli *except* the original conditional stimulus are now safe. We found no reduced fear of the original conditional stimulus nor the extinction generalization stimuli. However, the self-report data shows that the positive mood group has a similar level of self-report fear for the novel generalization stimulus as the extinction generalization stimuli, whereas the negative group has greater self-report fear of the former than the latter. This may suggest that the positive group treated the novel stimulus as a member of the extinction stimuli category, thus roughly equating their fear levels. Conversely, the negative group may not have developed the categorization that *all* generalization stimuli are safe, so their fear of the novel generalization stimulus may have been heightened relative to the extinction stimuli and relative to the positive mood group. Lastly, our findings regarding significant effects of mood induction were modest and not robust across measures. An alternative explanation for the effect of mood induction on novel generalization stimulus self-report fear is Type I error; perhaps this result occurred only by chance. Had there been more robust results, this would likely decrease the probability of Type I error as a potential explanatory factor.

There were several limitations of the present study. First, as stated earlier, we tested memory after we tested fear. Unfortunately, we were unable to test them simultaneously, and we chose to prioritize testing fear first over testing memory since our study is primarily a fear

conditioning study. Future studies would benefit from testing memory prior to fear to see if mood induction affects novel generalization stimulus fear through false memory. Second, acquisition and extinction were conducted on the same day, which likely reduced excitatory learning and thus the fear observed one week later at test (Myers, Ressler & Davis, 2006). Additionally, the pre-extinction mood induction may also be considered a post-acquisition mood induction. Future studies would benefit from having acquisition on one day and extinction on a second day. Third, the findings model a one-week interval between extinction and test. It is unclear how these results would extend over longer periods of time or multiple sessions of extinction, which would be relevant for treatment of anxious individuals. Lastly, the lack of mood induction effects on fear in this study may be due to deterioration of the mood induction during extinction. While the two mood induction groups had significantly different mood at the beginning of extinction, they were no longer different after extinction. This suggests that at some point during extinction, their moods ceased to be different from each other, which would reduce effect size. It is unknown at what point during extinction their moods ceased to differ, so future studies would benefit from conducting brief mood measurement during extinction.

In conclusion, the present study suggests that positive mood induction prior to extinction with a variety of generalization stimuli largely does not affect fear to the original conditional stimulus, the extinction stimuli, nor a novel generalization stimulus. However, we have one tenuous finding that positive mood induction resulted in less self-report fear of a novel generalization stimulus, though the pathway of this effect is unclear.

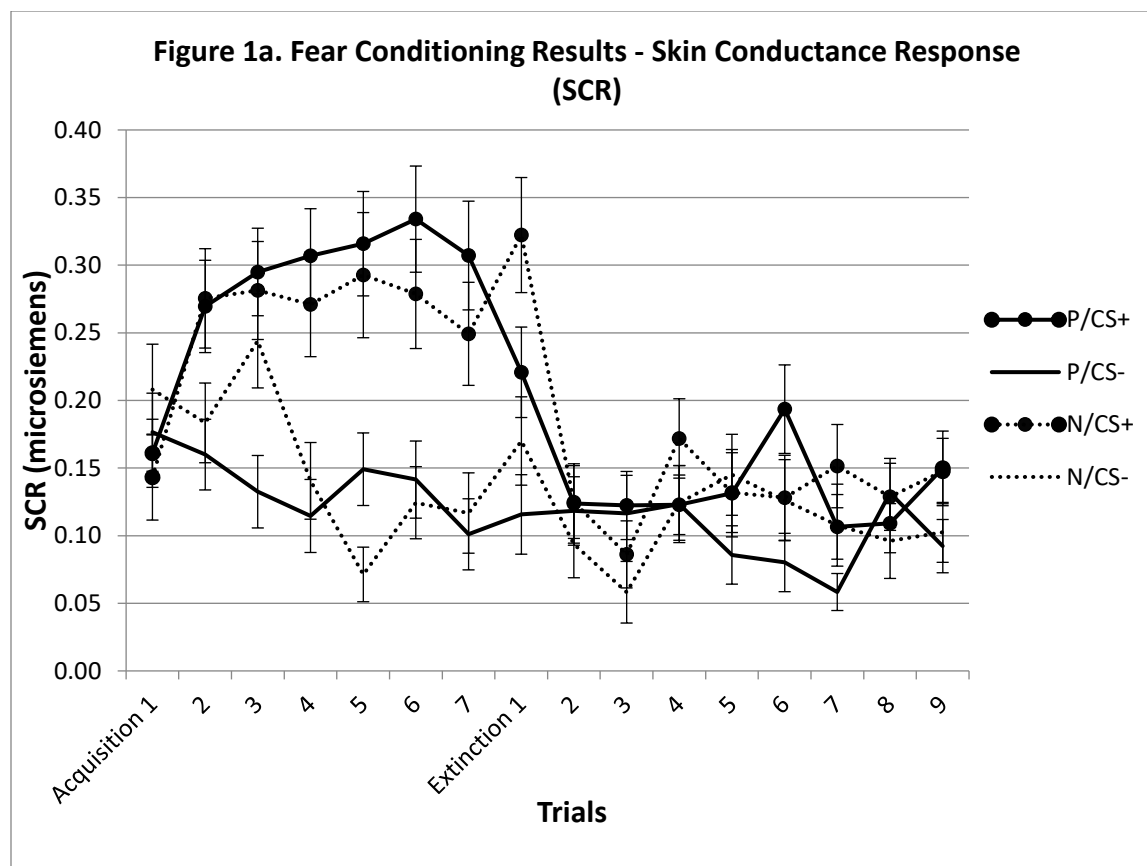
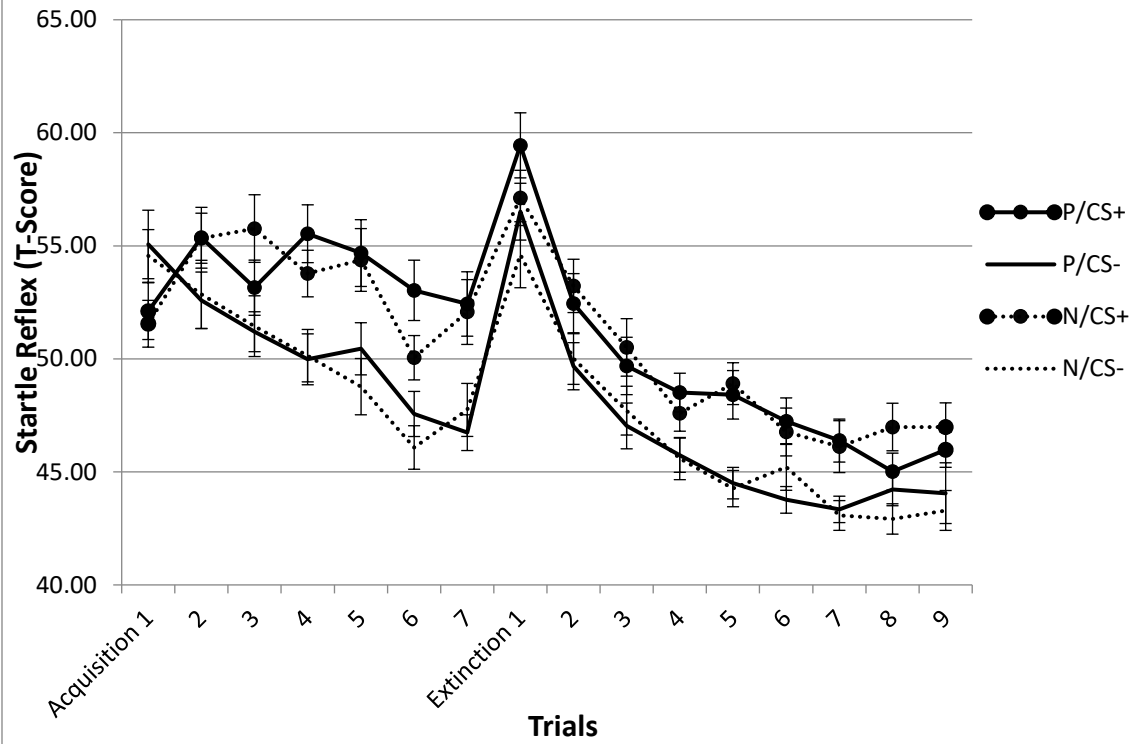
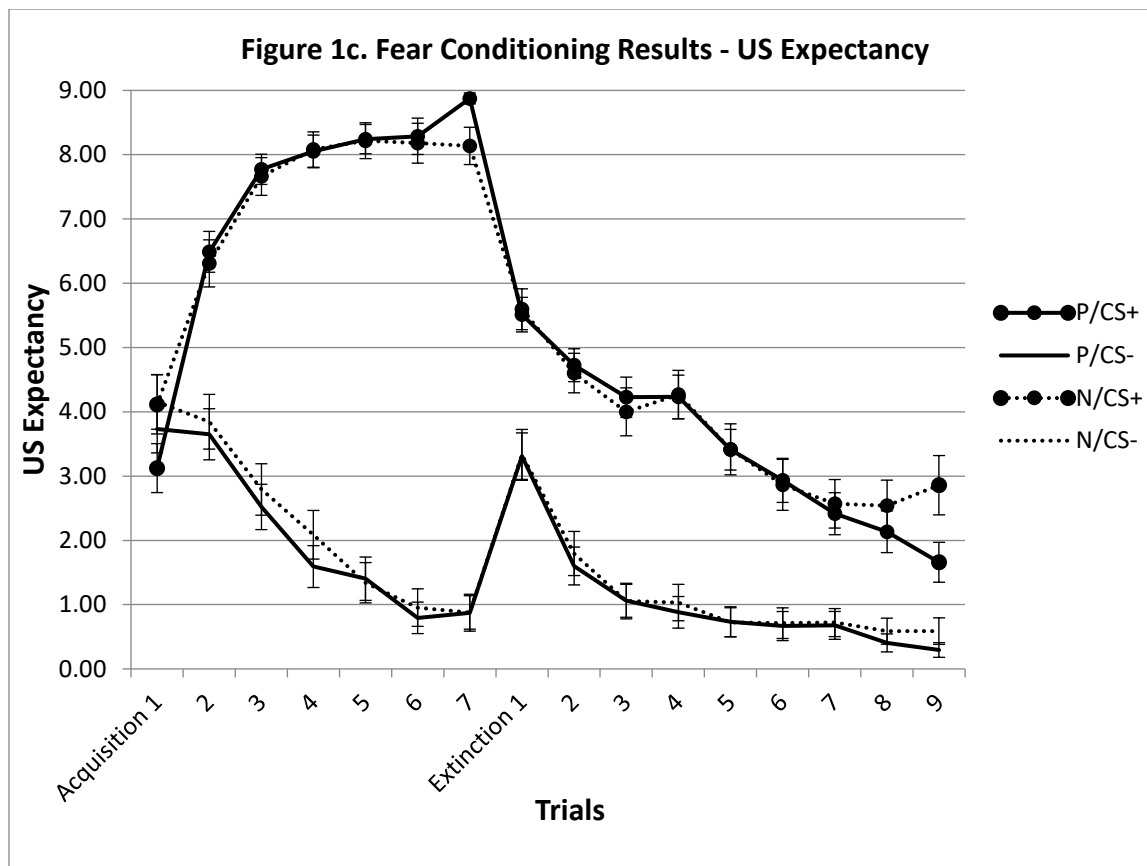


Figure 1b. Fear Conditioning Results - Startle Reflex





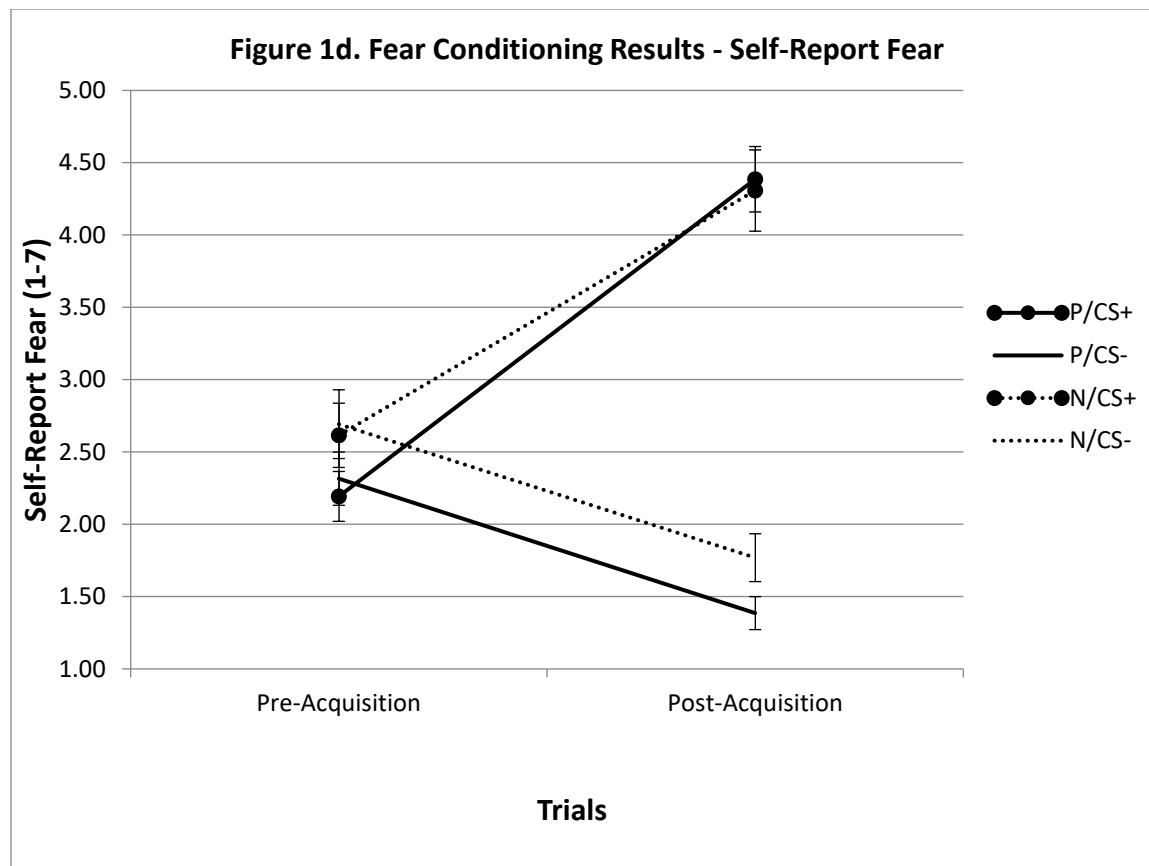


Figure 1

a-d present fear conditioning data across acquisition and extinction. Measures include skin conductance response (SCR), startle reflex, unconditional stimulus (US) expectancy, and self-report fear. Self-report fear was not measured after extinction. During acquisition, we presented the CS+ and CS-. During extinction, we presented GSs 1-9 once each and the CS- nine times. Thus, the "CS+" lines represent CS+ during acquisition and GSs during extinction. "P" stands for positive mood induction; "N" stands for negative mood induction. US Expectancy was measured on a 0-9 scale, where 0 = "Certain no electric shock", 4.5 = "Uncertain," and 9 = "Certain electric shock." Self-report fear was measured on a 1-7 scale, where 1 = "Not at all fearful of" and 7 = "Very fearful of." Error bars represent standard error.

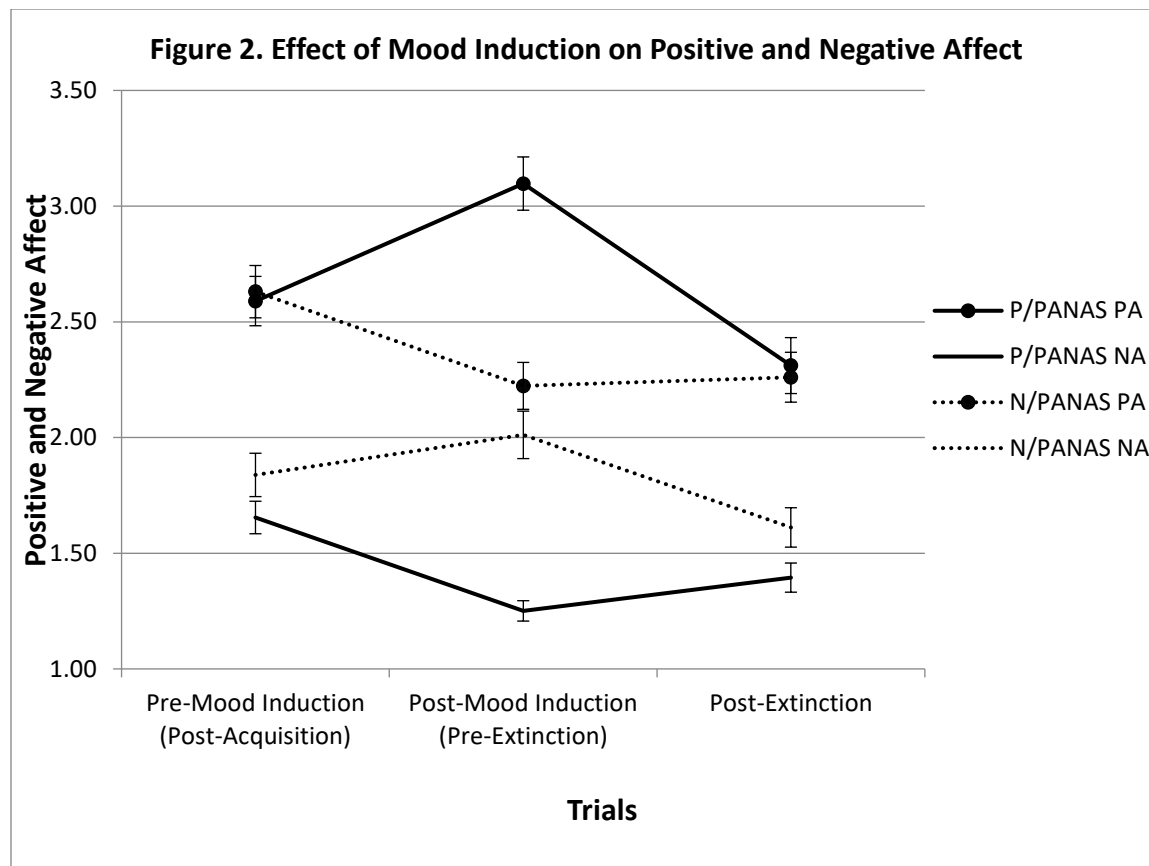
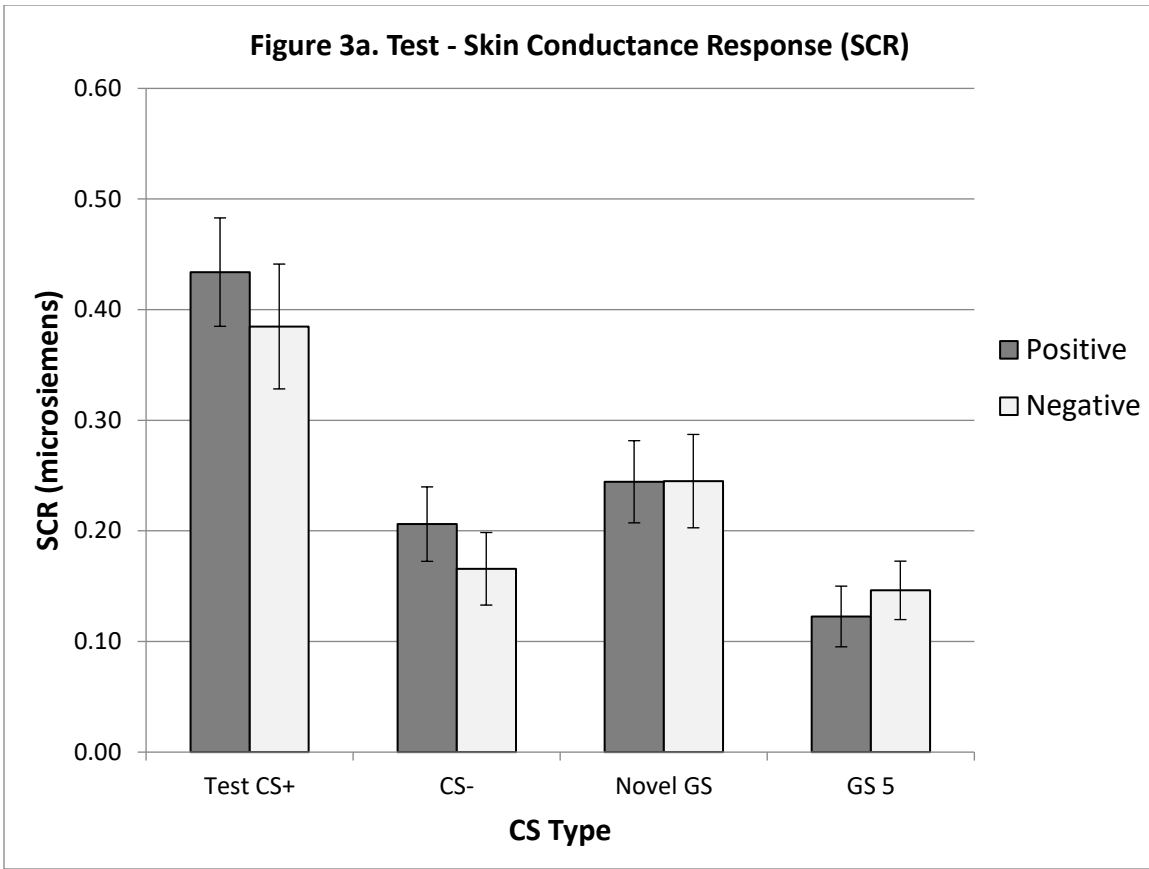
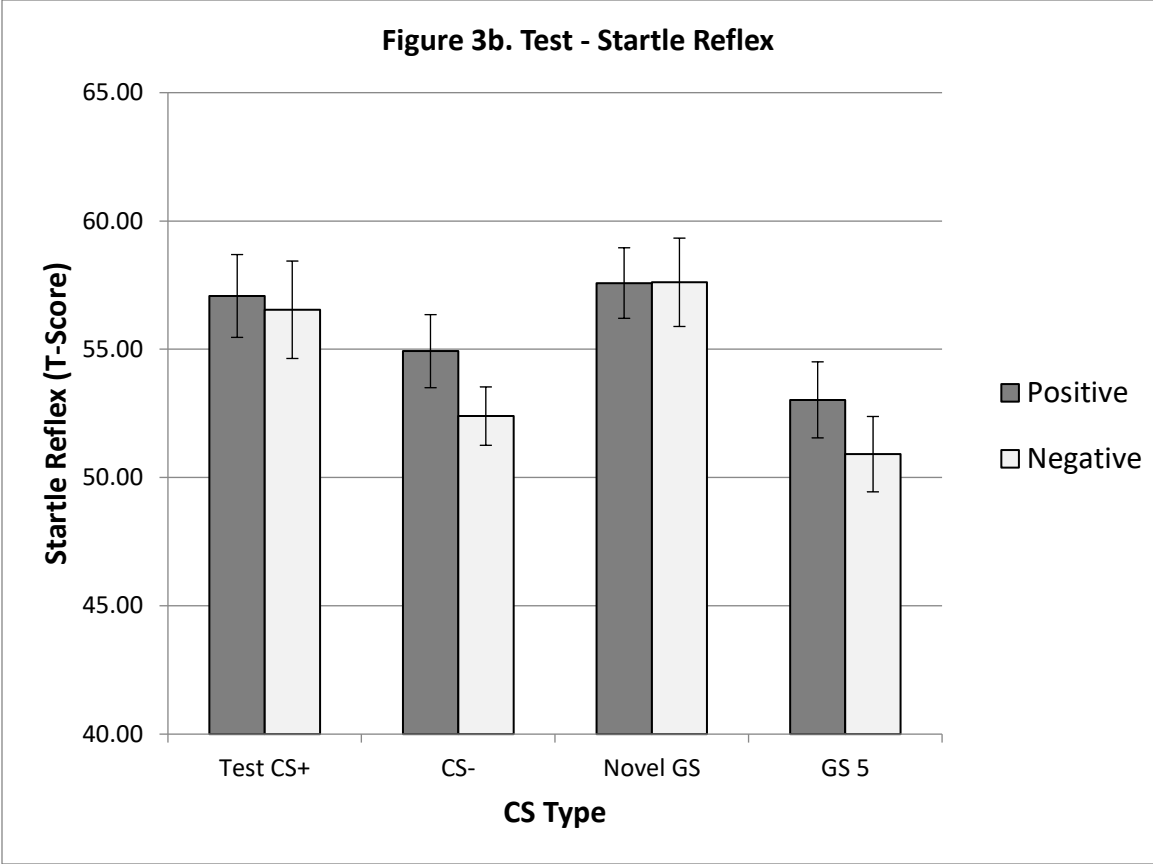
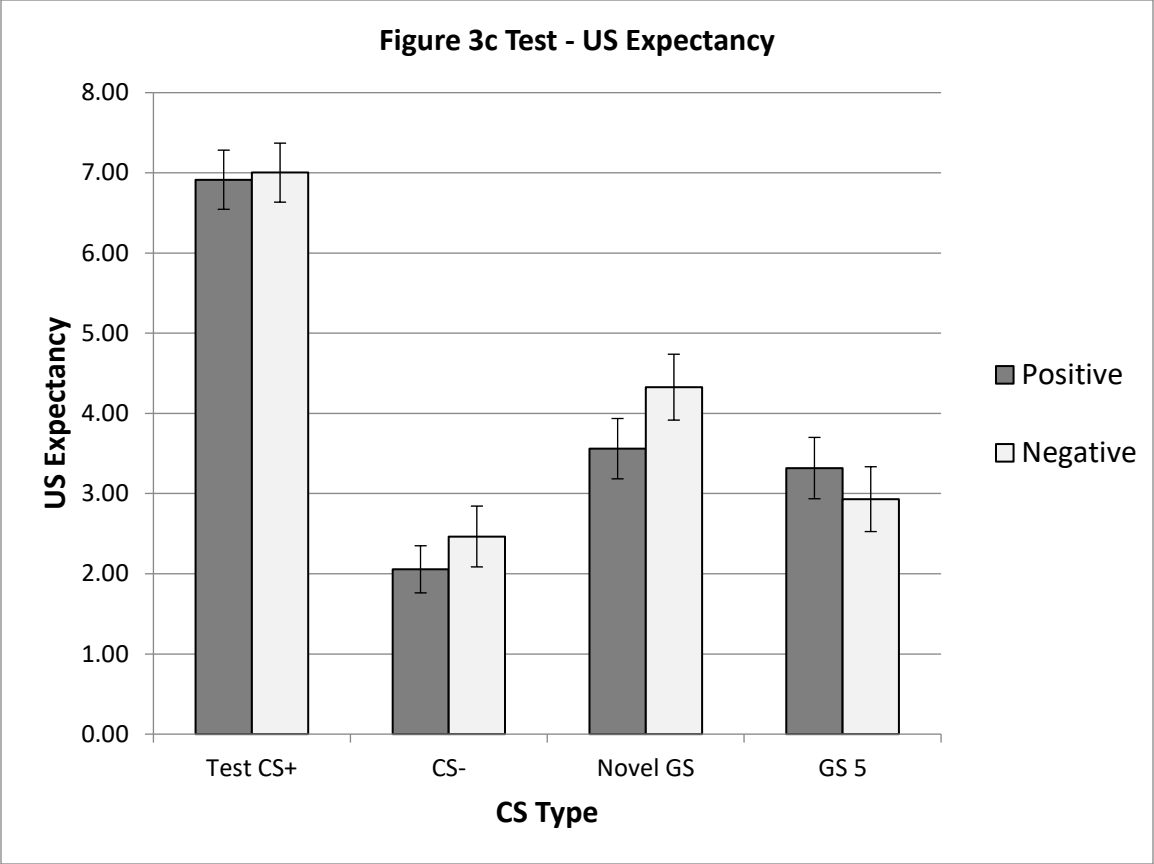


Figure 2

Presents the effects of positive and negative mood induction on positive and negative affect. Measurements include the positive and negative affect schedule (PANAS) positive affect (PA) subscale and PANAS negative affect (NA) subscale. The positive affect subscale is a composite score of the Joviality, Self-Assurance, and Attentiveness subscales. The measure of NA was the general NA scale. In the legend, "P" stands for positive mood induction; "N" stands for negative mood induction. PANAS PA and PANAS NA were measured on a 1-5 scale; higher scores indicate higher PA and NA. Error bars represent standard error.







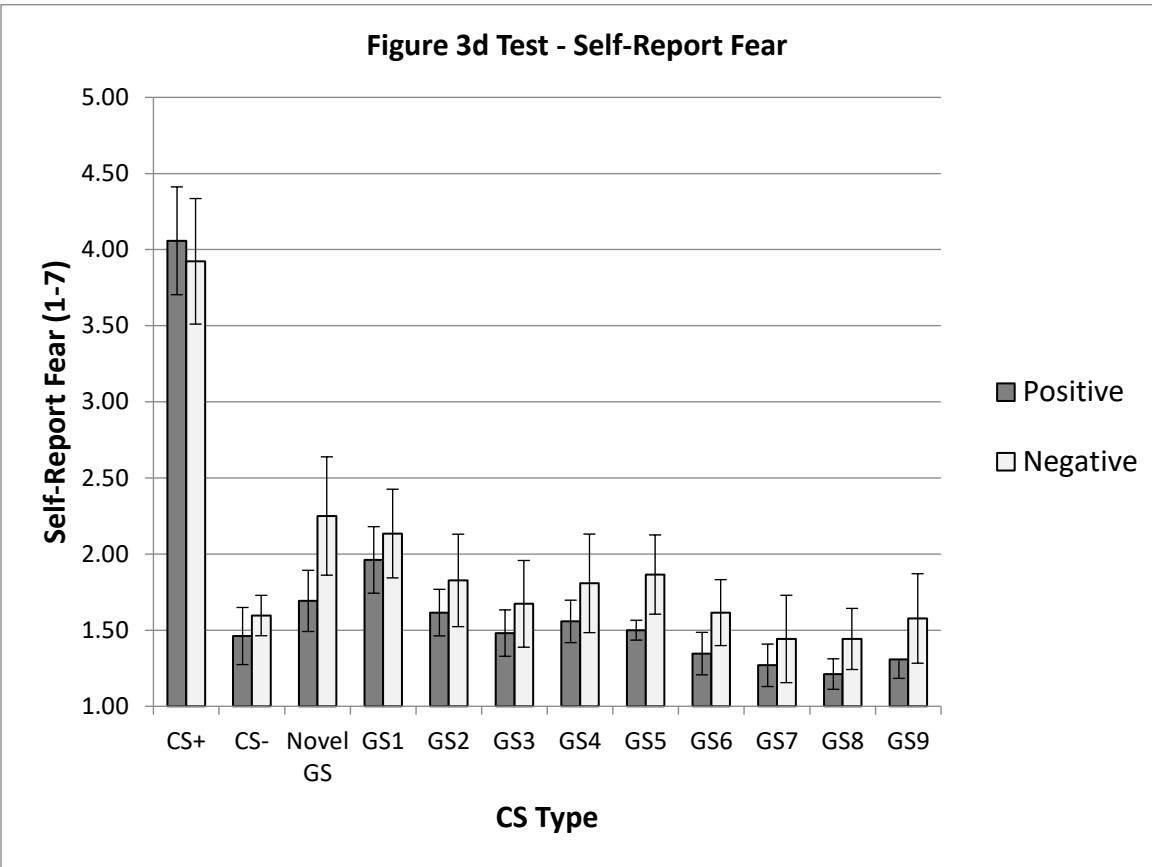


Figure 3

a-d present fear at test for the CS+, CS-, novel GS, and extinction GS(s) (i.e., GSs 1-9). Fear of GS 1-9 was measured by self-report only, whereas the remaining measures only tested GS 5. Measures include skin conductance response (SCR), startle reflex, unconditional stimulus (US) expectancy, and self-report fear. Results showed significantly less self-report fear of the novel GS for the positive group than the negative group (Figure 3d; $\chi^2(1) = 4.41$, $p = .036$). US Expectancy was measured on a 0-9 scale, where 0 = "Certain no electric shock", 4.5 = "Uncertain," and 9 = "Certain electric shock." Self-report fear was measured on a 1-7 scale, where 1 = "Not at all fearful of" and 7 = "Very fearful of." Error bars represent standard error.

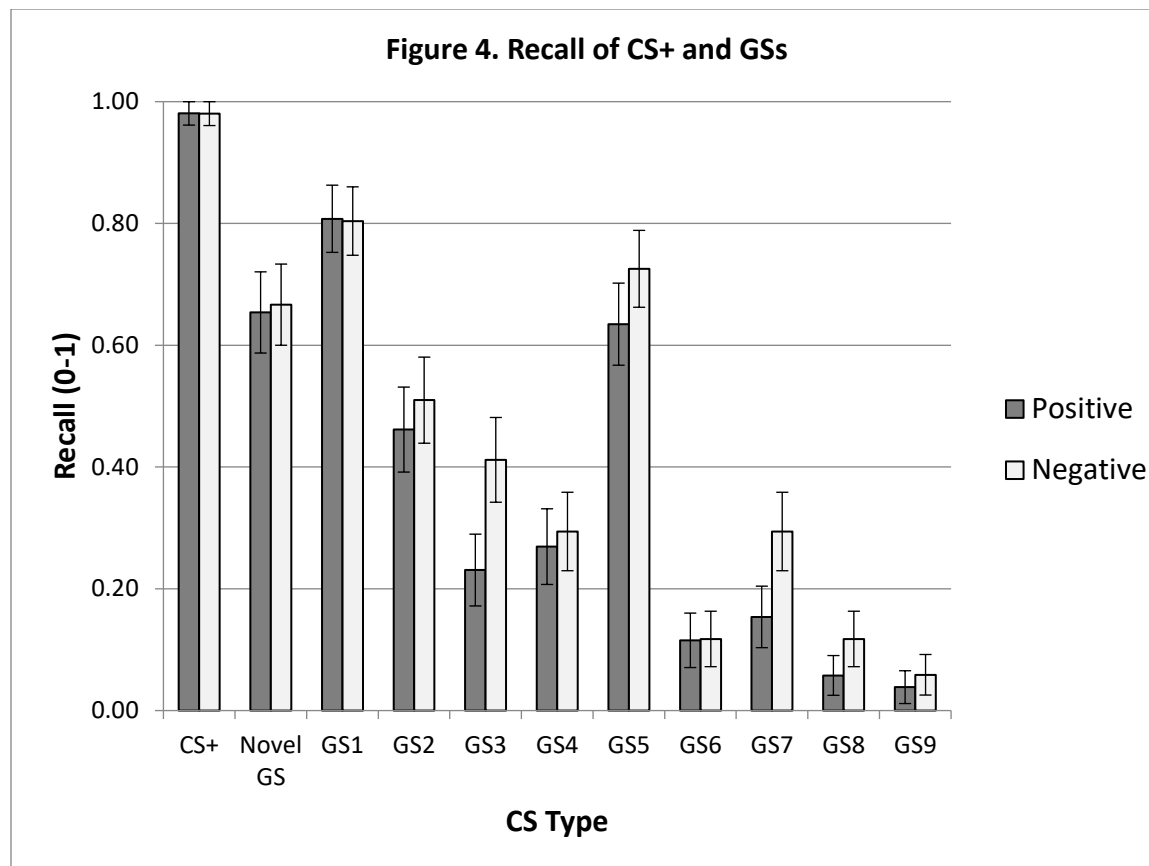


Figure 4

Presents recall of the CS+ and GSs. Recall was measured on Day 8 and assessed recall of viewing the CSs/GSs on Day 1. A score of 0 indicates not recalling the CS/GS, and a score of 1 indicates recalling the CS/GS. For all stimuli except the novel GS, higher scores indicate greater accuracy of recall. For the novel GS, higher scores indicate higher false recall. Error bars represent standard error.

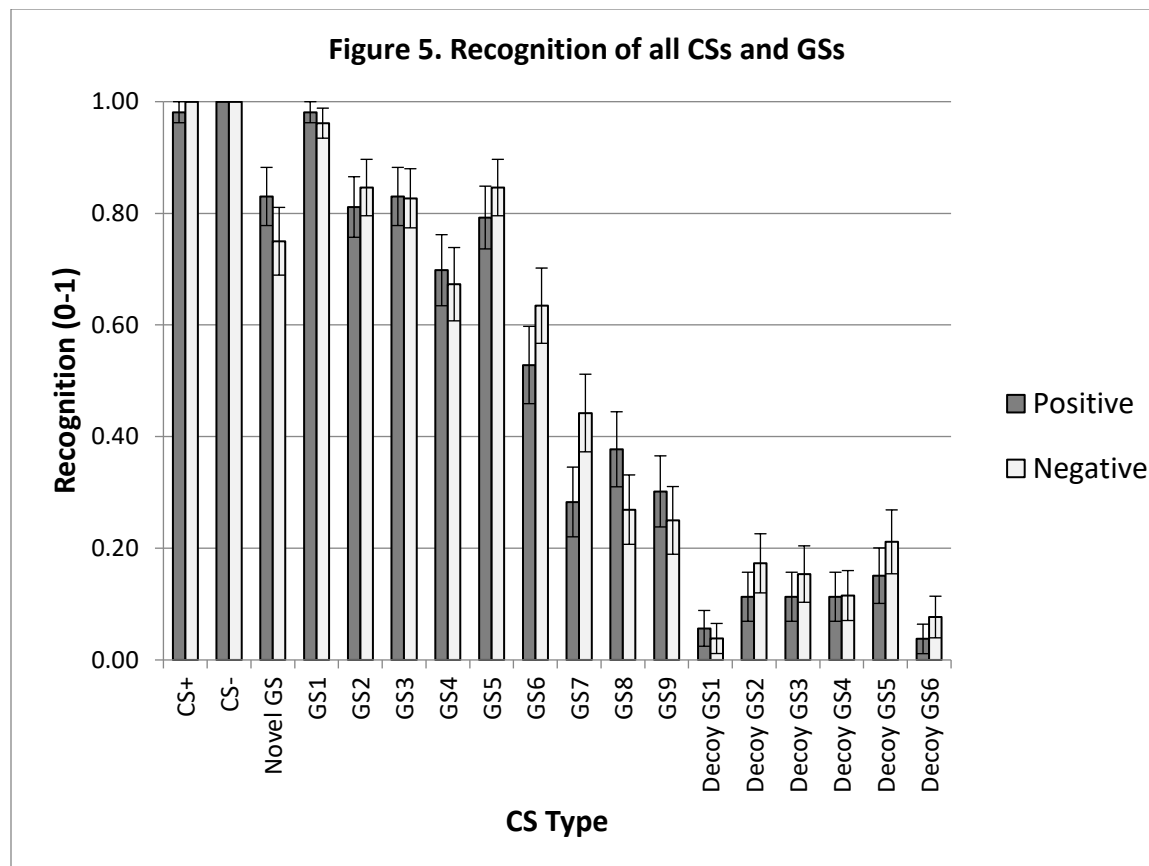


Figure 5

Presents recognition of the CS+, CS, the novel GS, the extinction GSs (GSs 1-9), and six decoy GSs that were not shown during any fear conditioning phase. Recognition was measured on Day 8 and assessed recognition of viewing the CSs/GSs on Day 1. A score of 0 indicates not recognizing the CS/GS, and a score of 1 indicates recognizing the CS/GS. For all stimuli except the novel GS and decoy GSs 1-6, higher scores indicate greater accuracy of recognition. For the novel GS and decoy GSs 1-6, higher scores indicate higher false recognition. Error bars represent standard error.

General Discussion

The three empirical studies in this dissertation assessed the effects of naturally occurring positive affect (Study 1) and experimentally manipulated positive affect (Studies 2 and 3) during extinction on levels of fear at test one week later. Study 1 tested fear at reacquisition; Study 2 tested spontaneous recovery, long-term extinction learning, and reacquisition fear; and Study 3 tested fear to a variety of extinguished generalization stimuli, fear to a novel GS, and fear to an unextinguished CS+. Across all three studies, we hypothesized that greater positive affect during extinction would result in less fear at test. One proposed mechanism was that higher positive affect during extinction would lead to greater semantic processing, which would lead to deeper encoding and better memory retention than lower positive affect (Brand, et al., 2007; Craik, 2002; Craik & Lockhart, 1972; Lee & Sternthal, 1999). A second proposed mechanism was that higher positive affect during extinction would result in relational processing – which is integrating incoming information with already-learned information – and that higher negative affect would result in referential processing – which is processing incoming information more independently of previously learned information (Clore & Huntsinger, 2007). During extinction, we posited this would result in greater integration of the inhibitory association with the already-learned excitatory association learned during acquisition. When the excitatory association is activated at a later time (e.g., return of fear), we posited the inhibitory association would be more activated in individuals with high than low positive affect, with the measured result being reduced fear. Additionally, in Study 3, we hypothesized that individuals with high positive affect would experience a false memory effect due to greater semantic processing (Storbeck & Clore, 2005). When presented with a variety of generalization stimuli from the same semantic category (e.g., colors), we predicted individuals in a positive mood would falsely remember seeing a color

(i.e., blue) that was not presented during extinction to a greater extent than individuals in a negative mood. By falsely remembering the non-presented color blue during extinction, we predicted individuals in a positive mood would have less fear of the novel generalization stimulus blue at test. Additionally, for Study 3, because individuals in a positive mood engage in more heuristic processing (Clore & Huntsinger, 2007) and categorize information more effectively (Nadler, et al., 2010) than individuals in a negative mood, we posited that individuals in a positive mood would better categorize all generalization stimuli as safe (i.e., “all colors except green are safe”) and possibly even the CS+ as safe (i.e., “all colors, including green, are safe”). By developing this category and heuristic rule, we predicted there would be less fear of the extinction generalization stimuli and a novel generalization stimulus, the latter of which would be subsumed under this category of safety.

The results overall only modestly supported the hypotheses. In Study 1 for reacquisition, naturally occurring higher positive affect before and after extinction predicted less fear during reacquisition than low positive affect as measured by skin conductance arousal and expectancy for the aversive event. Study 1 was a correlational design because the mood induction failed. Study 2 used a novel mood induction (i.e., positive or negative commercial videos) in an attempt to replicate Study 1’s findings and experimentally manipulate mood. While the mood induction was successful, there were no effects on spontaneous recovery, long-term extinction learning (i.e., last trial of acquisition to first trial at test), or reacquisition. Thus, Study 2 failed to support the hypotheses. The results of Study 3 results weakly supported the hypotheses. The positive mood group reported less fear of the novel generalization stimulus at test than the negative mood group. However, the primary hypothesized pathway (positive mood induction → greater false memory → less fear) was unsupported. This is likely due at least in part because of

methodological limitations; namely, memory was tested after trial presentations, so trials presentations likely affected memory and obstructed us from observing between-group differences in memory. A second explanation of our finding could be that, rather than the false memory effect, the positive group may have better categorized all generalization stimuli as safe than the negative group; the positive group had similar levels of fear for all generalization stimuli, whereas the negative group had greater fear of the novel generalization stimulus than most of the other generalization stimuli (see Study 3, Figure 3d). Thus, the positive group may have better learned the rule that “all colors but green (i.e., CS+) are safe” than the negative group, which could explain the lower fear of the novel stimulus in the positive group than the negative group. As a third explanation, because we only observed an effect with self-report fear and not with the other measures of fear, it is possible this effect was due to Type I error.

These studies were a novel attempt to investigate the effects of positive affect during extinction on later fear. I attempted to integrate the literatures of fear conditioning and the effects of positive affect on cognition. There are a few important considerations regarding why hypothesized effects were only modestly supported: 1) positive/negative affect conflicts, 2) hypothesized pathways, and 3) mood induction methods. For positive/negative affect conflicts, one consideration is whether individuals can be simultaneously fearful and in a positive mood during extinction. The debate regarding the relationship between positive and negative affect is long-standing (Russell & Carroll, 1999). Some researchers argue that positive and negative affect are independent factors (e.g., Watson, Clark, & Tellegen, 1988), whereas others argue they are bipolar factors with positive affect on one end of the spectrum and negative affect on the other end (Russell & Carroll, 1999). This debate is critical to this dissertation, as it questions whether positive mood induction is even possible when an individual is anxious or afraid during

extinction, and, if positive mood induction is possible, whether it will compromise the efficacy of extinction through mechanisms such as lowering US expectancy. Of note, positive affect did not significantly influence fear levels during extinction in any of the studies in this dissertation.

Specifically, psychometric evaluations of the Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988; Watson & Clark, 1999) show that positive and negative affect are orthogonal, meaning individuals can experience high or low positive affect while also experiencing high or low negative affect. For example, an individual who is promoted at work may simultaneously experience high positive affect (e.g., excitement, joy, pride) and high negative affect (e.g., anxiety and guilt about the implications on work-life balance). Similarly, the tripartite model (Clark & Watson, 1991) and hierarchical model of anxiety and mood disorders (Brown, Chorpita, & Barlow., 1998; Prenoveau et al., 2010; Watson, 2005) show that positive and negative affect are separable factors. Moreover, Larsen, Norris, and Cacioppo (2003) found that certain pictures, words, and sounds from the International Affective Pictures System (IAPS; Lang, Bradley, & Cuthbert, 1999) elicited mixed levels of positive and negative affect, although high levels of both positive and negative affect for a given stimulus were rare.

Conversely, proponents of the bipolar model state that positive affect is on one end of the spectrum and negative affect is on the other (Russell & Carroll, 1999), such that it is impossible to experience opposite emotions at the same time (e.g., happy and sad). They argue that positive and negative affect only appear to be independent because of methodological issues (e.g., item selection, the way in which affective items are measured, measurement error). They theorize that emotions exist on a two-dimensional matrix: one dimension is valence (ranging from negative to positive), and the other is arousal (ranging from low arousal to high arousal) (e.g., Lang, et al., 1993). Valid measures would capture the full breadth of positive and negative affect along the

range from low to high arousal. However, the PANAS includes positive and negative items that are predominantly high in arousal (Russell & Carroll, 1999). In the two-dimensional matrix of affect, Russell & Carroll (1999) argue that truly bipolar emotions are bipolar with regard to both valence and arousal. For example, “fear” is a high arousal, negative emotion, and its bipolar counterpart would be a low arousal, positive emotion (e.g., peaceful, calm, relaxed). The bipolar counterpart of “sad” (a medium arousal, negative emotion) would be happy (a medium arousal, positive emotion). Russell & Carroll (1999) provide evidence supporting the bipolarity of positive and negative affect once arousal is included as a factor. They state that truly bipolar emotions (separated by 180° on the valence-arousal emotion matrix) would have a correlation of -1.00 if measured appropriately. However, emotions that are separated by 90° would have a correlation of 0, which corroborates the near-zero correlation of positive and negative affect in the PANAS (Watson, Clark, & Tellegen, 1988; Watson & Clark, 1999).

While it is unclear on a theoretical level whether positive and negative affect are independent factors, the bipolar model seems to sufficiently explain the apparent orthogonality of positive and negative affect in some instances. Both models agree that individuals can possess high positive and negative affect with high arousal or low arousal, but not medium arousal or high arousal in one and low arousal in the other. In all three dissertation studies, positive affect reduced during extinction, which could possibly be due to some degree of incompatibility of positive and negative affect. By the end of extinction in Studies 2 and 3, the mood groups no longer significantly differed in terms of positive affect. This means that at some point during extinction, the mood groups probably no longer differed on positive affect, which would reduce or possibly eliminate our ability to observe the effects of positive affect on learning and fear reduction, depending on when during extinction mood ceased to differ between groups. Indeed,

the literature on positive affect and cognition is not typically conducted in an emotion-laden environment like fear conditioning. For example, Lee and Sternthal (1999) found that individuals in a positive mood were better able to remember items of a word list than individuals in a negative mood. Also, individuals in a positive mood were better able to categorize the items, as measured by the number of times items from the same category were clustered together during recall. From the false memory literature, Storbeck and Clore (2005) found that individuals in a positive mood who were presented multiple word lists – each word list composed of words from the same semantic category – had greater false memory of a semantically representative non-presented word than individuals in a negative mood. Importantly, the tasks involved in each of these studies were inherently emotionally neutral, whereas extinction inherently elicits fear and anxiety. Perhaps we did not observe the hypothesized effects in our study because extinction itself reduces positive affect and therefore its effects on learning and memory.

The mismatch in findings between Studies 1 and 2 on reacquisition is especially curious. While positive affect reduced in all studies from the start to end of extinction, it is possible we saw effects in Study 1 on reacquisition but not Study 2 because the naturally occurring positive affect may have been more stable in Study 1 than the experimentally manipulated positive affect in Study 2. Indeed, the pre-to-post extinction positive affect correlation was higher in Study 1 ($r = .806$) than in Studies 2 and 3 ($r_s = .620$ and $.615$, respectively). This may indicate a more consistent mood throughout extinction in Study 1 than Studies 2 and 3. Unfortunately, we did not measure mood during extinction – only before and after. The simplest prediction would be a spontaneous, linear decay in mood from the beginning to the end of extinction. However, because the first extinction trial elicits the most fear, it is plausible the mood induction effect may have been greatly reduced during the first extinction trial rather than a linear, gradual

deterioration throughout all of extinction. Future studies would highly benefit from very brief (e.g., one-item) measurement of mood after each extinction trial.

Second, it is important to consider the hypothesized pathways that may have differed between studies. As previously mentioned, one of Study 3's hypothesized pathways involved the false memory effect. However, this study was limited by testing memory after test trial presentation, which likely affected memory for the presented trials and reduced/eliminated our ability to observe between-group memory differences. This may have been the reason why our hypothesized positive mood induction → greater false memory → lower novel stimulus fear pathway was unsupported, even though positive mood induction predicted less fear of the novel generalization stimulus than negative mood induction. Future studies would benefit from testing memory first and then fear. Additionally, we (Zbozinek, Holmes, & Craske, 2015) assessed the effects of pre-extinction mood induction on reinstatement fear and found that positive mood induction reduced reinstatement fear as measured by startle reflex and self-report fear compared to negative mood induction. However, there was an additional hypothesized pathway that was not theoretically relevant in these dissertation studies: that positive mood would increase positive post-extinction CS+ valence, which would reduce reinstatement fear (Dirikx, et al. 2004; Dirikx., et al., 2007; Hermans, et al., 2005; Zbozinek, Prenoveau, et al., 2015). Indeed, we (Zbozinek, Holmes, & Craske, 2015) found that pre-extinction mood induction predicted higher post-extinction CS+ valence, which predicted less reinstatement fear. Although structural equation modeling also found a second, separate path from pre-extinction positive affect to test day positive affect to reinstatement fear (not involving CS+ valence), perhaps the reason we saw stronger effects in this study were due to the CS+ valence mediational route, which were not present in the three dissertation studies.

Third, the effects may be dependent on the type of mood induction or the duration of mood induction. We (Zbozinek, Holmes, & Craske, 2015) used positive imagery training (PIT) as a positive mood induction versus positive verbal training (PVT) as a negative mood induction to assess their effects on CS+ valence and reinstatement fear. PIT and PVT involve standardized procedures in which an individual is presented with the same 100 hypothetical audio scenarios each 10-13 seconds in duration (e.g. Holmes, et al., 2006; Holmes, Lang, & Shah, 2009; Nelis, Vanbrabant, Holmes, & Raes, 2012). The resolutions to these scenarios are ambiguous until the last word or last few words, but they all end positively. For example, “It’s your birthday, and your partner reaches over to you with a present. You open it and feel incredibly *happy*.” The ending (in italics) is positive. PIT and PVT only differ in their instructions: PIT participants are trained to imagine each of the scenarios and then to rate the vividness of their mental image, whereas PVT participants are trained to concentrate on the words and meaning of each scenario and then rate how difficult it was to understand the scenarios. Because imagining information has a stronger impact on emotions than simply verbally comprehending information, PIT results in greater positive affect than PVT (Holmes, et al., 2006). Additionally, PIT and PVT take approximately 30 minutes.

Studies 2 and 3 of this dissertation involved mood inductions of viewing positive and negative commercial videos. The duration of induction in Study 2 was approximately 12 minutes, whereas the duration of induction in Study 3 was under five minutes. Perhaps the lower duration of mood induction in Studies 2 and 3 results in shorter-lasting effects than the 30-minute duration of Zbozinek, Holmes, and Craske (2015). Alternatively, we (Zbozinek, Holmes, & Craske, 2015) confounded higher positive affect with imagery training and lower positive affect with verbal training. Perhaps the effects in that study were due to the imagery training and

not positive affect specifically. This could also explain the effects of Study 1 of this dissertation, as PIT and PVT were used as mood inductions, although they failed to achieve significance in changing mood. Perhaps, though, the effects on imagery versus verbal training were strong enough and confounded enough with positive affect to allow us to observe the correlational type effects of positive affect on reacquisition. Indeed, in Study 1, the PIT group reported using significantly more imagery than PVT, and PVT reported using significantly more verbal comprehension than PIT. Additionally, greater use of verbal comprehension was significantly negatively correlated with post-mood induction positive affect, and greater use of imagery was marginally positively correlated with positive affect. This could explain in Study 1 why positive affect before and after extinction predicted reacquisition fear – because of its association with imagery and verbal training. However, it is unclear why imagery training versus verbal training would affect extinction learning. Perhaps imagery training itself enhances learning by having individuals imagine and rehearse the inhibitory association more deeply throughout extinction and more emotionally experience the fear and therefore inhibitory learning, which could lead to greater memory of the inhibitory association and fear reduction.

Additionally, it is important to consider the results from a learning theory perspective. Because the effects of positive affect on extinction learning is a novel area of research, we unfortunately have very little research to draw from. The only other studies examining the effects of positive affect on learning found that positive affect reduced fear to the CS- in individuals with high trait anxiety (i.e., Geschwind, et al., 2015; Meulders, Meulders, & Vlaeyen, 2014). Conceivably, this occurred because individuals high in trait anxiety have difficulty learning safety or discriminating the danger cue from other cues (Boddez, et al., 2012; Craske, Waters, et

al., 2008; Lissek, et al., 2009), and positive affect increased positive expectations of the CS-, which reduced fear.

However, there has been research on appetitive-aversive conflict during learning in the form of superconditioning effects. Dickinson (1977) Experiment 1 found that compound presentation of A (a trained excitator of an appetitive US: food) and B (a neutral stimulus) led to greater fear of B when paired with an aversive US (i.e., shock) than when A was presented without food. Similarly, Experiment 2 found that an appetitive excitator blocked extinction of an aversive excitator when presented in compound during extinction. Leung, Holmes, and Westbrook (2016) found congruent results. From a learning theory perspective, the compound presentation of an appetitive CS with a neutral CS during aversive conditioning resulted in superconditioning, which is an enhancement in excitatory conditioning that results from presenting a neutral stimulus in compound with an inhibitor or, in this case, an appetitive CS. This prediction is in line with the Rescorla-Wagner model (1972) if, like an aversive inhibitor, an appetitive CS is able to take a negative learning value. However, this is qualitatively different from a mood induction, as these superconditioning studies involve manipulating CS/US associations in appetitive and aversive directions. The mood inductions in this dissertation presumably did not enter a relationship with the US (or, if they did, it would be in a negative occasion setting manner or an inhibitory direction since shocks did not occur during mood induction), and the mood induction was not presented in compound with CSs. Thus, it is unlikely that the mood induction itself would affect changes in learning as they would in the superconditioning studies.

Additionally, Monti, et al. (2016) found that an appetitive experience during a reconsolidation phase reduced fear at test. They theorized that if an aversive CS were presented for reconsolidation, a subsequent unrelated, emotionally opposite (i.e., positive, appetitive)

experience could disrupt the reconsolidation of the CS as a fearful memory. To this end, rats underwent acquisition and a reconsolidation phase for context fear. After presenting the context briefly for reconsolidation purposes, the rats were placed in a different context and given free access to either water or a sucrose solution – the latter being a more positive experience. Their results showed that context fear was reduced when rats were provided voluntary consumption of sucrose solution compared to those provided with water. This suggests that a positive emotional experience in one context *after* briefly entering an aversive context led to less fear of the aversive context, suggesting a disruption of reconsolidation of the fear memory. However, this differs from our studies, as our mood induction was conducted prior to extinction, and Monti, et al. (2016) conducted the positive experience after a reconsolidation reactivation trial. Also, our studies involved extinction, whereas Monti, et al. (2016) involved reconsolidation.

There are other effects to consider from a learning theory perspective. First, counterconditioning involves aversive-appetitive conflict. However, counterconditioning occurs when a CS that was previously paired with an aversive US is now paired with an appetitive US (or vice versa). This does not apply to our mood induction, as the mood induction was conducted prior to extinction and was not paired with the CS+. However, if every CS+ presentation during extinction resulted in a positive mood induction, this could conceivably be counterconditioning, but this was not the case in our studies. Second, it is possible that negative occasion setting could be a factor. Negative occasion setting is depicted as $A^+, B \rightarrow A^-$, where A leads to the US when presented alone, but A does not lead to the US when preceded by B. Our mood induction may have served as B. However, like other learning phenomena, occasion setting is best learned through repeated trials (e.g., Holland, 1984). Also, the valence of the mood induction would be irrelevant from an occasion setting perspective, which would lead us to predict no differences in

fear between positive and negative mood induction. Critically, however, the mood induction would need to be presented again at test, which we did not do in our study. Thus, it appears that occasion setting is not central to our studies. However, mood could become relevant if mood itself can become a negative occasion setter rather than the induction (i.e., when in a specific mood, the CS does not predict the US). If so, we would predict that congruency in mood during extinction and at test would result in less fear than incongruency. We did not, however, manipulate mood both before extinction and before test. Similarly, second-order conditioning is important to consider. Second-order conditioning would suggest that the mood induction predicts the CS, and the CS predicts the US. However, like with occasion setting, this would likely require repeated trials, and we would not expect differences between positive and negative mood inductions. Fourth, perhaps positive affect was present during extinction, but its effects were overshadowed by the CS. Mood and the CS could conceivably be considered two separate CSs presented in compound during extinction, in which case the actual CS likely overshadowed any learning to that could be attributable to mood as a CS. However, our posited mechanisms of the effects of mood on learning and fear do not entail mood entering in a direct association with the US, and we have no way of measuring the degree to which mood entered an association with the US in these studies. Additionally, mood was likely less salient as a potential CS than the actual CS presented.

Thus, it is unclear why the results of these dissertation studies only provided modest support of the hypotheses and how appetitive-aversive interactions may be at play. However, these considerations pose new hypotheses about the effects of positive affect on extinction learning for future studies. First, it would be important to have a mood induction that maintains mood separation between groups throughout all of extinction. Second, briefly measuring mood

throughout extinction would help the investigator know whether mood induction was successfully manipulated throughout all of extinction. Third, future studies could parse apart the effects of imagery training, verbal training, and mood induction. For instance, a future study could assess the effects of positive imagery training, positive verbal training, and positive commercial videos on return of fear. This way, the effects of positive affect and imagery training can be independently assessed. Fourth, with relevance to Study 3, future studies could assess memory for extinction generalization stimuli and the novel generalization stimulus prior to testing fear to them. Fifth, future studies could evaluate the effects of positive mood induction on exposure therapy in a clinical setting.

In conclusion, the effects of positive affect on fear reduction were modest, and there were no observed beneficial effects of high negative affect in any of the studies. The results suggest that higher positive affect during extinction may reduce reacquisition fear and may reduce self-report fear of a novel generalization stimulus. With relevance to exposure therapy, this suggests it may be slightly beneficial for individuals to be in a positive mood during exposures with regards to reacquisition of fear and generalization of extinction learning, though future studies would need to determine the mechanisms more clearly and whether positive affect influences exposure therapy for anxiety disorders.

Appendix A: Study Stimuli

All Studies: Unconditional stimulus (US) = electric shock

Studies 1 and 2:

All conditional stimuli (CSs) were counterbalanced.

CS+1

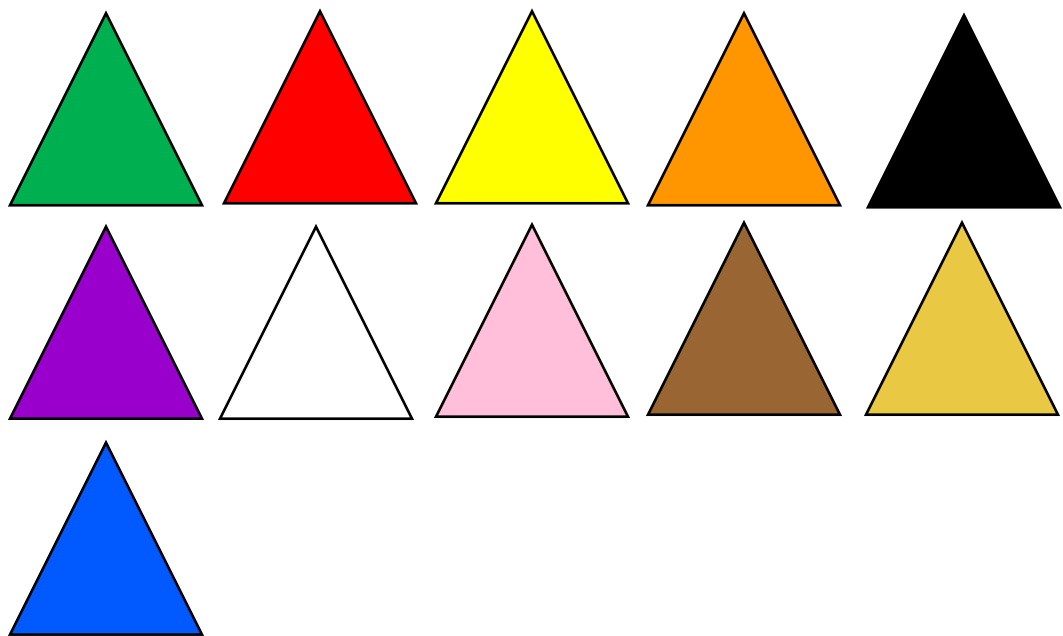


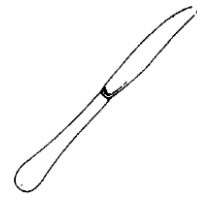
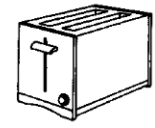
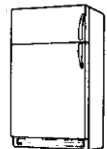
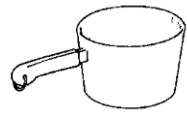
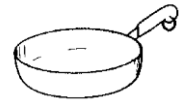
CS-



Study 3:

Conditional stimuli (CSs) and generalization stimuli (GSs) each belonged to one of two semantic categories: colors or kitchen items (Battig & Montague, 1969; Snodgrass & Vanderwart, 1980). Participants were counterbalanced with regards to whether their CS+ and GS category was colors or kitchen items. For individuals counterbalanced to have colors as their CS+/GS category, the CS+ was a green triangle, the novel GS at test was a blue triangle, the extinction GSs were the remaining colors (i.e., red, yellow, orange, black, purple, white, pink, brown, and gold), and the CS- was a drawing of a fork (from the kitchen items semantic category). For individuals counterbalanced to have kitchen items as their CS+/GS category, the CS+ was a drawing of a fork, the novel GS at test was a drawing of a knife, the extinction GSs were the remaining kitchen items (i.e., spoon, pan, pot, stove, bowl, cup, refrigerator, glass, and toaster), and the CS- was a green triangle (from the colors semantic category).





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