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Safety Signaling During Threat: An Investigation of Social  
Support Figures as Prepared Safety Stimuli

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

by

Erica Anne Hornstein

2016



## ABSTRACT OF THE DISSERTATION

Safety Signaling During Threat: An Investigation of Social  
Support Figures as Prepared Safety Stimuli

by

Erica Anne Hornstein

Doctor of Philosophy in Psychology

University of California, Los Angeles, 2016

Professor Naomi Ilana Eisenberger, Chair

The ability to learn about and identify cues that predict danger is critical for survival, allowing individuals to safely and efficiently traverse the world. The process by which this learning occurs, fear learning, has been well documented, and within this literature it has been demonstrated that certain stimuli are more readily associated with threat than others. Namely, prepared fear stimuli, stimuli that have historically threatened survival, are more readily associated with threat, leading to more exaggerated fear responses that are harder to extinguish. However, little work has been done to examine the parallel concept of prepared safety stimuli—stimuli that have historically promoted survival and thus are less readily associated with fear and inhibit the fear response. Social support figures, who provide protection, care, and resources, ultimately benefitting survival, are one likely category of prepared safety. The research outlined in this dissertation seeks, for the first time, to explore the role and function of social support as a

prepared safety stimulus. To begin, Paper 1 develops a definition of prepared safety stimuli and then tests whether social support fulfills the parameters of these stimuli. Results revealed that social support stimuli are less readily associated with fear and inhibit the conditional fear response, indicating that social support is a category of prepared safety stimuli. Papers 2 and 3 built on these findings, and the effect of social support on fear learning processes was examined. Findings revealed that the presence of social support prevents the formation of fear associations during fear acquisition (Paper 2), and inhibits return of fear after fear extinction (Paper 3). Altogether, the results from this dissertation shed light on the properties of prepared safety stimuli in general, and social support stimuli in particular, and serve as a foundation for future exploration of these unique safety effects.

The dissertation of Erica Anne Hornstein is approved by

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University of California, Los Angeles

2016

To Cesar & Olivia, for making me want to be the best social support figure I can be

## TABLE OF CONTENTS

I. Introduction	1
II. Paper 1	5
A. Abstract	6
B. Introduction	7
C. Method	9
D. Experiment 1: Method and Results	11
E. Experiment 2: Method and Results	14
F. Experiment 3: Method and Results	20
G. Figure 1 and Figure Caption	11
H. Figure 2 and Figure Caption	13
I. Figure 3 and Figure Caption	15
J. Figure 4 and Figure Caption	18
K. Figure 5 and Figure Caption	19
L. Figure 6 and Figure Caption	22
M. Discussion	22
N. References	27
O. Supplemental Materials	30
III. Paper 2	42
A. Abstract	43
B. Introduction	44
C. Method	47
D. Results	50



E. Figure 1 and Figure Caption	49
F. Figure 2 and Figure Caption	51
G. Discussion	51
H. References	54
I. Supplemental Materials	57
IV. Paper 3	62
A. Abstract	63
B. Introduction	64
C. Method	66
D. Results	71
E. Figure 1 and Figure Caption	69
F. Figure 2 and Figure Caption	73
G. Discussion	74
H. References	80
I. Supplemental Materials	82
V. Conclusion	88
VI. References for Introduction and Conclusion	91

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During graduate school, I have also been lucky enough to have the support of an amazing network of lab-mates, office-mates, and friends. Thank you to everyone in the Social Affective Neuroscience and Social Cognitive Neuroscience Labs for listening to me talk about the same material over and over for the past six years, and for always giving amazing support and feedback. Most especially, thank you to Keely Muscatell, Tristen Inagaki, Janine Dutcher, Mona Moieni, and Kate Haltom, without whom I would not have made it through this program in one piece. Additionally, I owe many thanks to

Liz Castle, Jen Forsyth, & Clarissa Cortland, who have kept me grounded throughout many ups and downs and have become some of my closest friends. Finally, thank you to Annie Weiss, who has helped me sort through all of the different challenges that come with growing up and has kept me sane through all of these years.

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The work in the following dissertation was a team effort. The study concepts for Paper 1 were developed by Naomi and myself, and, with the help of Michael Fanselow, we designed the research, analyzed and interpreted the data, and drafted the manuscript. Papers 2 and 3 were similarly a joint effort between Naomi and myself, with the data discussed in Paper 3 having been collected by Kate Haltom and Kanika Shirole. These papers will be submitted for review in the next several months. Finally, credit must be given to the participants who agreed to come into the lab, be hooked up to equipment, and receive electric shocks. This work was completed with the help of a Graduate Research Fellowship from the National Science Foundation, which afforded me the time to complete these studies, and the Wendell Jeffrey and Bernice Wenzel Term Chair in Behavioral Neuroscience awarded to Naomi Eisenberger.

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Hornstein, E. & Eisenberger, N. (in prep) Examining the role of safety stimuli during fear learning.

Hornstein, E. & Eisenberger, N. (in prep) Social support enhances extinction of learned fear responses.

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**Talk**, *December 2014*

Erica Hornstein, “Safety Signaling During Threat: An Investigation of Social Support Figures as Prepared Safety Stimuli.”

**Social & Affective Neuroscience Society Meeting 2013**, San Francisco, CA

**Poster Presentation**, *April 2013*

Erica Hornstein & Naomi Eisenberger, “Examining the Safety Signal Value of Social Support: An Investigation of Prepared Safety Stimuli.”

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### **Research Positions**

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## INTRODUCTION

In order to navigate the world, human-beings must adaptively learn about both threatening and safe cues on a daily basis. Given the importance of appropriately responding to stimuli in the environment, understanding the types of stimuli encountered, and the ways in which they function, is of paramount importance. Although considerable research has examined prepared fear stimuli, stimuli that have historically threatened survival and are more readily associated with aversive events (Cook, Hodes, & Lang, 1986; Ohman, Fredrikson, & Hugdahl, 1978; Ohman & Mineka, 2001; Seligman, 1971), little work has examined the opposite construct of prepared safety stimuli, stimuli that have historically enhanced survival and thus are less readily associated with fear and also inhibit fear responding (Jacobs & LoLardo, 1977).

Based on the crucial role social ties play in survival, it is possible that social support figures are one category of prepared safety stimuli—signaling security and protection from danger, reducing fear responding, and attenuating fear learning. Indeed, perceived social support has been demonstrated to increase feelings of safety (Bowlby, 1969), reduce appraisals of threat (Coan, 2008; Master, et al., 2009; Eisenberger, Master, Inagaki, Taylor, Shirinyan, et al., 2011), and mitigate psychological and physiological threat responses (Epley, 1974; Thorsteinsson & James, 1999; Hennessy, Kaiser, & Sachser, 2009; Kiyokawa, Takeuchi, & Mori, 2007), suggesting that social support may be a powerful natural safety signal.

In order to explore the characteristics and parameters of prepared safety stimuli, the following presents three papers in which the role and function of social support as a prepared safety stimulus is investigated. Drawing on theory and methods from both the

social support and Pavlovian conditioning literatures, this dissertation focuses on the safety signaling properties of social support and the impact they have on the fear learning process. The goal of each paper is briefly outlined below.

*Paper 1: A safe haven: Social support figures as prepared safety stimuli*

Paper 1 poses the question of whether social support figures are prepared safety stimuli. Drawing on Pavlovian conditioning theory and literature, we first developed a definition of prepared safety stimuli and then tested whether social support figures fulfilled these parameters. Based on the concept of conditioned inhibitors—cues that, through specific training, are learned to be associated with the lack of an aversive event and therefore inhibit the fear response for that event (Rescorla, 1969)—we defined prepared safety stimuli as performing the same functions as conditioned inhibitors, but without requiring any specific training. Thus, in order to assess whether social support is one category of prepared safety stimuli, we examined whether social support stimuli passed the two tests of a conditioned inhibitor without any in-lab training. First, we tested whether social support figure stimuli passed the retardation-of-acquisition test, less readily becoming associated with fear compared to stranger or neutral stimuli (study 1). Second, we tested whether social support figure stimuli passed the summation test, inhibiting the fear response to other conditional fear stimuli in comparison to stranger or neutral stimuli (study 2). And third, we examined whether prepared safety effects were unique to social support, comparing fear learning during a retardation-of-acquisition test for social support figure stimuli, familiar stimuli, and rewarding stimuli (study 3). Together, these studies will develop a definition of prepared safety stimuli and establish whether social support is one category of prepared safety. Additionally, this work will

create the opportunity for new ideas and perspectives on the relationship between social support and the ways in which we learn about fear.

*Paper 2: Prepared safety as a buffer: The effect of social support on fear acquisition*

To explore the impact of social support on fear learning processes, Paper 2 investigates whether social support prevents individuals from forming fear associations for other cues. During a fear acquisition procedure, images of social support figures or strangers were paired with conditional stimuli, and fear acquisition was evaluated for conditional stimuli in the social support-paired condition compared to the stranger-paired condition. Results from this paper have the potential to uncover the impact of social support, as a category of prepared safety stimuli, on fear learning for other cues. In addition, building on work that has demonstrated the link between social support and positive mental and physical health outcomes (House, Landis, & Umberson, 1998; Cohen & Wills, 1985; Cacioppo, Hughes, Waite, Hawkey, & Thisted, 2006), this paper will shed light on one possible route through which social support might be improving health—buffering individuals against psychological and physical stress by preventing the formation of fear associations and consequently reducing activation of the fear response.

*Paper 3: Social support enhances extinction of learned fear responses*

To further explore the impact of social support on fear learning processes, Paper 3 sought to investigate whether social support enhances the process by which fear is extinguished for other cues. Based on previous findings showing that the presence of social support stimuli during fear extinction lead to continued inhibition of the fear response after the social support stimulus was removed (*Paper 1*: Hornstein, Fanselow, & Eisenberger, in press), a fear conditioning study was run in which social support figure



stimuli and stranger stimuli were paired with conditional fear stimuli during extinction. We then examined whether, after fear extinction was complete and the social support stimulus or stranger stimulus was removed, there was a return of fear either immediately following fear extinction, during a fear reinstatement test 24 hours following fear extinction, and during a fear reinstatement test 2 weeks following fear extinction. Although counter to what might be expected based on previous literature (Lovibond, Davis, & O'Flaherty, 2000; Lovibond, Mitchell, Minard, Brady, & Menzies, 2009; Rescorla, 2003) results from this work will clarify the impact of social support on fear extinction as well as reveal the distinct safety signaling properties held by prepared safety stimuli.

*Overarching goal:*

Together, these papers will help inform our understanding of the role and function of social support as a category of prepared safety stimuli by first developing a definition of prepared safety stimuli and testing whether social support fulfills it (*Paper 1*) and then evaluating the impact of social support on fear learning (*Paper 2*) and fear extinction (*Paper 3*). This line of research is pursued in the hopes that the results will guide future research on the relationship between social support and fear learning processes, ultimately providing the foundation to investigate the ways in which social support might be used to improve mental and physical health.

Paper 1:

A safe haven: Social support figures as prepared safety stimuli

Erica Anne Hornstein, Michael S. Fanselow, & Naomi Ilana Eisenberger

In Press in *Psychological Science*

## Abstract

Although fear conditioning research has demonstrated that certain survival-threatening stimuli, namely *prepared fear stimuli*, are more readily associated with fearful events, little research has explored whether a parallel category exists for safety stimuli. We examined whether social support figures, who have typically benefited survival, are '*prepared safety stimuli*,' a category which has not been explored previously. Across three separate studies, findings indicated that: 1) social support stimuli were less readily associated with fear (retardation-of-acquisition test), 2) social support stimuli inhibited conditional fear responses to other cues (summation test) and this inhibition continued even after the support stimulus was removed, and 3) these effects were not simply due to familiarity or reward as both familiar and rewarding, but not social support, stimuli were readily associated with fear. These findings suggest that social support figures are one category of prepared safety stimuli that may have long-lasting effects on fear learning processes.

Being able to learn cues that predict threat or danger, a process called fear learning, is critical for survival. Indeed, studies of Pavlovian fear conditioning have shown that fear responses are rapidly acquired to a neutral cue associated with an aversive event (e.g., shock) (Davey, 1992; Delgado, Olsson, & Phelps, 2006; Pavlov, 1927). Moreover, in both human and non-human animals, fear learning occurs more effectively with certain stimuli (Cook & Mineka, 1990; Newton et al., 2004; Sigmundi, Bouton, & Bolles, 1980). Thus, *prepared fear stimuli*—stimuli that have historically threatened survival (snakes, spiders)—are more readily associated with aversive events, leading to exaggerated conditional fear responses that are then harder to extinguish (Cook, Hodes, & Lang, 1986; Ohman, Fredrikson, & Hugdahl, 1978; Ohman & Mineka, 2001; Seligman, 1971).

However, little research has examined the parallel notion of *prepared safety stimuli*—stimuli that may have historically benefited survival and thus may be more readily associated with safety and therefore inhibit fear responding (Jacobs & LoLardo, 1977). One category of stimuli that seems a likely candidate for inclusion as prepared safety stimuli are social support figures, who, over the course of evolutionary history, have provided individuals with protection, care, and resources, ultimately promoting survival. Indeed, research has shown that pictures of social support figures activate neural regions implicated in detecting safety and lead to reductions in distress in response to negative events (Eisenberger et al., 2011). However, no work has examined whether social support figures act as prepared safety stimuli.

To examine this, we borrowed from work on one kind of learned safety signal, a conditioned inhibitor. Specifically, in the context of fear conditioning, conditioned

inhibitors not only signal safety from experiencing an aversive event, but also inhibit the fear response for that event (Rescorla, 1969). Prepared safety stimuli should thus perform the same functions as conditioned inhibitors, but, unlike conditioned inhibitors, should not require specific training in the lab to acquire this safety value. It is also possible that they may hold other properties that lead to a more powerful inhibition of the fear response beyond that of conditioned inhibitors. Therefore, we conducted the two tests of conditioned inhibitors for the fear response (Rescorla, 1969) to determine if social support figures belong in the prepared safety category, as indicated by their passing these tests without any lab-based training.

In Experiment 1, we conducted a retardation-of-acquisition test to assess whether the acquisition of a conditional fear response is retarded or inhibited when the association is being formed with a social support figure stimulus, defined here as the people from whom an individual perceives receiving the most social support (care, resources) on a daily basis. Specifically, we examined conditional fear responses in response to pairing a social support figure stimulus with an aversive event (electric shock) as well as in response to pairing stranger and neutral stimuli with an aversive event. We hypothesized that, although conditional fear responses would be acquired to the stranger and neutral stimuli, no conditional fear response would be acquired to the social support stimuli.

In Experiment 2, we conducted a summation test to assess whether social support figure stimuli inhibit other conditional fear responses. For this test, after training participants to acquire conditional fear responses to neutral stimuli, we paired these now fearful neutral stimuli with social support stimuli (as well as stranger and neutral stimuli) and examined whether the conditional fear response was inhibited. We hypothesized that,

although stranger and neutral stimuli would not inhibit the fear response, social support stimuli would weaken the fear response elicited by other learned threats when they were present, and possibly even after they were removed. Together, these tests allowed us to evaluate whether social support stimuli are prepared safety stimuli.

Finally, in order to isolate the aspects of social support stimuli that might be driving these effects, Experiment 3 tested whether conditional fear responses could be acquired to familiar or rewarding stimuli. This allowed us to determine whether other confounding features of social support stimuli, such as their familiarity or reward value, might be driving the effects observed here. We hypothesized that, although conditional fear responses would be acquired to familiar (images of current professors) and rewarding (images of favorite foods) stimuli, no conditional fear response would be acquired to the social support stimuli.

## **Method**

### **Participants**

Data were analyzed from a final sample of 20 participants (*mean age*=21.05, 8 *females*) for Experiment 1, 20 participants (*mean age*=19.65, 14 *females*) for Experiment 2, and 20 participants (*mean age*=20.10, 14 *females*) for Experiment 3 (see supplemental materials). Sample sizes were based on those used in previous research (see: Olsson et al., 2005; Schiller et al., 2010). Participants were recruited from the University of California, Los Angeles (UCLA) community. Experimental procedures were approved by the UCLA IRB.

## **Overall Procedure**

Because the overall procedures for all three experiments were similar, we first outline the overall procedures and then go through the unique fear conditioning procedure for each experiment.

Participants first completed a telephone screening and a pre-screening session to determine if they were eligible to participate in the study (see supplemental materials). During the pre-screening session, they were asked to fill out a social support figure questionnaire that required them to select “the two individuals who give you the most social support on a daily basis” (Experiments 1 and 3) or “the individual who gives you the most support on a daily basis” (Experiment 2), and then to rate how much social support these individuals give them everyday on a scale of 1-10. They were then instructed to send digital photographs of the social support individuals to the experimenter before the experimental session

Participants then returned to the lab for the experiment session, during which they first underwent a shock calibration procedure to determine the appropriate level of shock to be applied during the experiment (see supplemental materials). The shock was calibrated individually for each participant such that it was extremely uncomfortable, but not painful. After this, the unique fear conditioning procedures for each experiment were employed (see below). During the experiment, Skin Conductance Response (SCR), an index of physiological arousal, was collected as a measure of learned fear (see SOM). Data was pre-processed based on suggested guidelines (Figner & Murphy, 2011) and then scored using separate scoring strategies to find the mean scores that represented responses during the different stages (see supplemental materials).

## Experiment 1

### Method

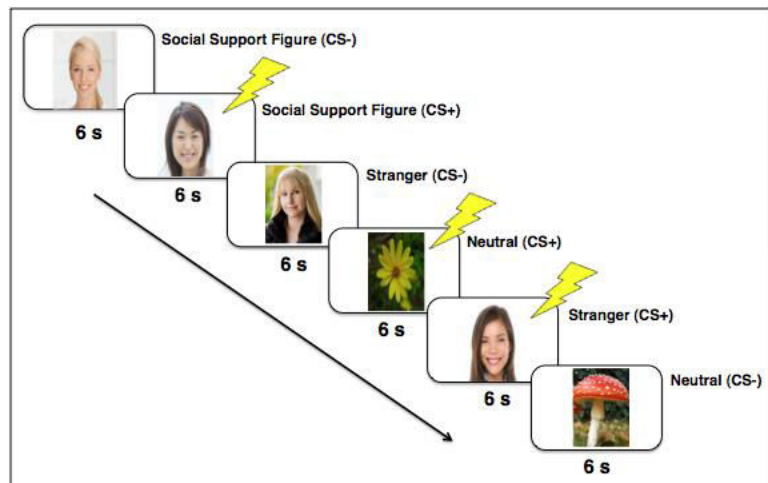
Experiment 1 used a retardation-of-acquisition procedure to examine whether it was difficult to acquire a conditional fear response to an image of a social support figure, but not to an image of a stranger or neutral object.

*Retardation-of-Acquisition Procedure.* Participants underwent a session of fear conditioning with 3 sets of stimuli: (1) two images of social support figures, (2) two images of strangers (age, gender and ethnicity-matched to the social support figures), and (3) two neutral images

(flowers, mushrooms). For each stage of the experiment (habituation, acquisition, extinction), each image was presented in a pseudorandom order for 6 seconds, followed by a 1.5 second inter-stimulus-interval (ISI)

before the next image presentation.

In the Habituation stage, participants saw four non-reinforced (without shock) presentations of each image. There were no pre-existing characteristics of the stimuli within any condition that led to heightened SCR ( $p's > .250$ ), thereby eliminating the possibility that pre-existing differences in the stimuli created later differences in SCR.



**Figure 1.** Example of shock/image pairings during the acquisition stage of Experiment 1. Participants were presented with 3 sets of images: (1) two images of social support figures, (2) two images of strangers, and (3) two neutral images. One image from each set was consistently paired with electric shock (CS+) while the other image from each set was never paired with shock (CS-). Conditional fear responses were measured by calculating the difference between the SCR for the CS+ vs. the CS- for each set.



Next, during the Acquisition stage (see Fig. 1), participants saw six presentations of each image. One image from each condition was consistently presented (100% reinforcement schedule) with a co-terminating 200ms shock (CS+), while the other image from the same condition was never presented with shock (CS-). SCR responses to these images would later be compared within each condition (e.g., social support CS+ vs. social support CS-), serving as a tight comparison condition. Importantly, there were no differences in social support ratings for the social support figures whose images were paired with shock (mean=8.80) compared to those whose images were never paired with shock (mean=8.55),  $t(19)=.893$ ,  $p>.250$ , 95% CI [-0.34,0.84].

After the Acquisition stage, participants had a break during which they viewed a short movie about airplanes. Finally, during the Extinction stage, participants saw six non-reinforced presentations of each image in order to extinguish any conditional fear responses. Pseudorandom orders were counterbalanced across participants, and SCR was collected during all stages of the experiment.

*Data Analysis Strategy.* Before the data were analyzed, we determined whether each participant acquired conditional fear to the CS+ from any of the three conditions (social support, stranger, neutral), by examining whether the acquisition mean for the CS+ was greater than the acquisition mean for the CS- for each condition (by any amount of SCR;  $CS+ - CS- >0$ ). If a participant acquired conditional fear to at least one condition, the data was included, otherwise the participant's data was excluded from the experiment (due to a high likelihood of a lack of attention or unawareness of CS-US contingencies, see Dawson & Shell, 1985).

In order to assess fear acquisition, paired sample t-tests were run comparing the acquisition means for the CS+ to the CS- within each condition (e.g., social support CS+ vs. social support CS-) in order to determine if SCR aroused by the CS+ image was significantly higher than that aroused by the CS-, indicating that a fear response was acquired to that condition (see supplemental materials for details).

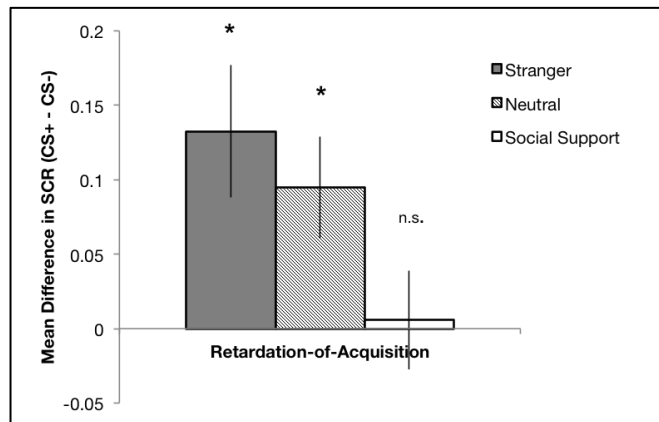
In addition, we ran a repeated-measures ANOVA to evaluate the effect of condition (social support, stranger, neutral) on fear acquisition, using mean difference scores from each stimulus set (CS+ vs. CS- within each condition). We followed this ANOVA with post-hoc paired-samples t-tests comparing the mean difference in SCR for social support stimuli vs. stranger and neutral stimuli.

## Results

To determine whether social support stimuli passed the retardation-of-acquisition test without any prior training, we examined whether participants could form fear associations with images of their social support figures, as well as images of strangers and neutral objects. As expected,

conditional fear responses were acquired to both the stranger and neutral stimuli.

Specifically, there was significantly greater SCR to the CS+ compared to the CS- for both the neutral,  $t(19)=2.76, p=.012, 95\% \text{ CI } [0.17,0.02]$  and the stranger stimuli,  $t(19)=2.98,$



**Figure 2.** SCR from the retardation-of-acquisition test in Experiment 1. Conditional fear responses were evaluated by comparing the SCR for each CS+ to the CS- within each category (stranger, neutral, social support). After acquisition, there was a conditional fear response to both stranger and neutral stimuli, but not for social support stimuli. Error bars indicate standard errors. Asterisks indicate a statistically significant difference score, and “n.s.” indicates non-significant.

$p=.008$ , 95% CI [0.22,0.03] (Fig. 2). However, no conditional fear response was acquired to the social support figure stimulus,  $t(19)=-.170$ ,  $p>.250$ , 95% CI [-0.08,0.06] (Fig. 3). Additionally, examining the effect of condition (social support, stranger, neutral) on fear learning revealed a significant effect,  $F(2,38)=4.00$ ,  $p=.027$ ,  $\eta_p^2=.174$ , such that fear acquisition to the social support stimuli was significantly reduced relative to fear acquisition to the stranger,  $t(19)=-2.51$ ,  $p=.021$ , 95% CI [-0.23,-0.02] or neutral stimuli,  $t(19)=-2.45$ ,  $p=.024$ , 95% CI [-0.17,-0.01]. These results demonstrate that fear is not readily acquired to social support stimuli, indicating that social support stimuli pass the retardation-of-acquisition test without any lab-based training—one of the tests necessary for identifying a prepared safety stimulus.

## Experiment 2

### Method

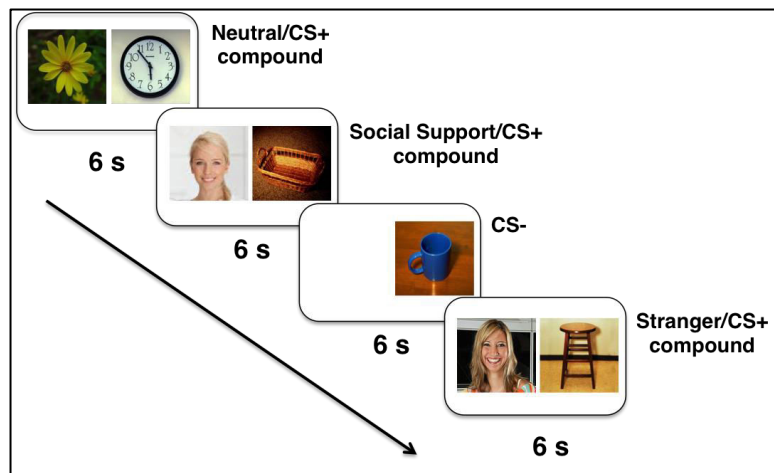
Experiment 2 used a summation procedure to examine whether social support figure stimuli, but not stranger or neutral stimuli, could reduce conditional fear responses to other learned fear stimuli.

*Summation Procedure.* Participants underwent a session of fear conditioning with images of 4 neutral stimuli (basket, stool, cup, clock) that would later be paired with a secondary image from one of three conditions: (1) an image of a social support figure, (2) an image of a stranger (age, ethnicity, and gender-matched to the social support figure), and (3) a neutral image (flowers, mushrooms). For each stage of the experiment, each image was presented in a pseudorandom order for 6s, followed by a 6s ISI.

In the Habituation stage, participants saw three non-reinforced (without shock) presentations of each of the original neutral images. There were no differences in the mean SCR score for each of the three future CS+s compared to the future CS-, verifying that there were no pre-existing characteristics of any of the stimuli that led to more arousal ( $p$ 's  $>.250$ ).

Next, in the Acquisition stage, participants saw 4 presentations each of three of the neutral images consistently presented (100% reinforcement schedule) with a co-terminating 200ms shock (CS+), and 10 presentations of a neutral image that was never paired with shock (CS-). After the acquisition stage, participants had a break during which they viewed the first 3 minutes of a short movie about airplanes.

In the Summation stage (see Fig. 3), participants saw 4 non-reinforced presentations of each CS+ paired with a secondary image (social support, stranger, neutral), and 4 non-reinforced presentations of the CS- in a pseudorandom order. The CS+/secondary image compound pairings were



**Figure 3.** Example of the CS+/secondary image compounds presented during the summation stage of Experiment 2. Prior to summation, participants were trained to acquire conditional fear responses to neutral stimuli; during this acquisition stage (not shown here), participants were presented with four different neutral stimuli, one of which was never paired with shock (CS-) and three of which were consistently paired with shock (CS+s). Following acquisition was the summation stage (shown above), during which no shock was applied and each of the CS+s was co-presented with an image of: (1) a social support figure, (2) a stranger, or (3) a neutral object, while the CS- was presented alone. Finally, there was a test stage (not shown here), in which the CS- and the 3 CS+s were once again presented alone (with no secondary images), and no shock was applied. Conditional fear responses were measured by comparing the difference in SCR for each CS+ or each secondary image/CS+ compound (during the summation test) to the CS-.

counterbalanced across participants so that each neutral CS+ type was paired with a different category of secondary image equally across participants. After the summation stage, participants had a second break during which they viewed the last 3 minutes of the short movie.

In the final Test stage, participants saw 4 non-reinforced presentations of each of the CS+s and of the CS-. The pseudorandom order of trials was counterbalanced across participants. SCR data was collected during all stages of the experiment.

*Data Analysis Strategy.* Before the data were analyzed, we determined whether each participant acquired conditional fear to each CS+, by examining whether the acquisition mean for the CS+ was greater than the acquisition mean for the CS- (by any amount of SCR;  $CS+ - CS- > 0$ ). If a participant did not acquire conditional fear to all three CS+s, the participant's data was excluded from the experiment. This was done to ensure that a conditional fear response was acquired to each CS+ before examining whether each secondary image could inhibit the conditional fear response during the summation stage of the experiment.

For the acquisition stage, paired sample t-tests were run comparing the acquisition means for each of the CS+s to the CS- acquisition mean in order to determine if the SCR aroused by the CS+ was significantly higher than that aroused by the CS-, indicating that a fear response had been acquired to the image (see supplemental materials for details).

For the summation stage, paired sample t-tests were run comparing the summation means for each CS+/secondary image compound to the CS-. If these comparisons were significant, it was inferred that a fear response was exhibited and that

no inhibition occurred. However if no fear response was exhibited, it was considered that inhibition had occurred.

For the test stage, paired sample t-tests were run comparing the test stage means for each of the CS+s alone (after the secondary image was removed) to that of the CS-. If these comparisons were significant, it was inferred that a fear response was exhibited.

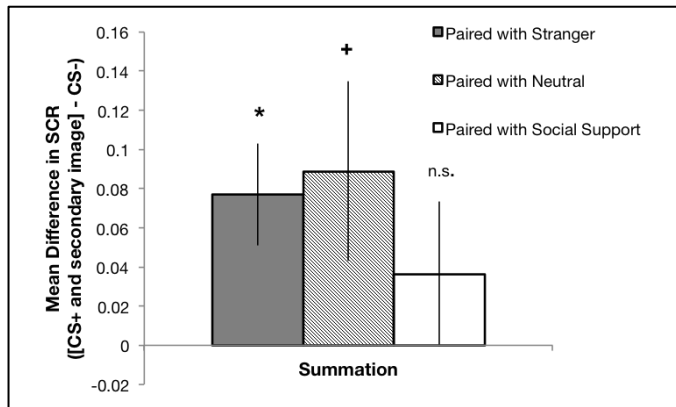
In addition, we ran repeated-measures ANOVAs to evaluate the effect of condition on: 1) fear inhibition, using mean difference scores for each compound stimulus from the summation stage (vs. CS-) and 2) return of fear, using mean difference scores for each original CS+ (vs. CS-) from the test stage. We followed these ANOVAs with post-hoc paired-samples t-tests examining the mean difference in SCR for the images paired with social support stimuli vs. those paired with stranger or neutral stimuli.

## **Results**

To explore whether social support stimuli passed the summation test without any prior training, we examined whether conditional fear responses to neutral stimuli were inhibited by the presentation of social support stimuli. Because testing summation requires examining whether conditional fear responses are reduced in the presence of an additional stimulus, we first needed to ensure that participants exhibited conditional fear responses to the different CS+s. Indeed, for the final sample, there was a significant conditional fear response to the CS+s that would later be presented with the neutral secondary image,  $t(19)=6.64$ ,  $p<.001$ , 95% CI [0.09,0.16], the stranger secondary image  $t(19)=5.65$ ,  $p<.001$ , 95% CI [0.09,0.19] and the social support secondary image  $t(19)=5.21$ ,  $p<.001$ , 95% CI [0.08,0.18], indicating that fear was acquired to each of these

CS+s. Additionally, there were no significant differences in SCR across the CS+s,  $F(2,38)=.228, p>.250, \eta_p^2=.012$ , indicating that equivalent levels of acquisition occurred.

Once conditional fear responses were established for each of the three CS+s, we examined participants' responses to the combination of the CS+ and the secondary image. As expected, when the CS+ was accompanied by the stranger image, there was no inhibition of the conditional fear response, as evidenced by a



**Figure 4.** SCR from the summation test in Experiment 2. Conditional fear responses were evaluated by comparing the SCR for each CS+/secondary image pairing for each of the three categories (stranger, neutral, social support) to that of the CS-. During summation, there was a conditional fear response still present for CS+s paired with stranger and neutral stimuli, but not for CS+s paired with social support stimuli. Error bars indicate standard errors. Asterisks indicate a statistically significant difference score, “+” indicates a marginal difference score ( $p=.055$ ), and “n.s.” indicates non-significant.

significantly greater SCR for the stranger/CS+ compound compared to the CS-,  $t(19)=3.08, p=.006, 95\% \text{ CI } [0.02,0.12]$  (Fig. 4). Similarly, when the CS+ was accompanied by the neutral image, there was also no inhibition of the conditional fear response,  $t(19)=2.05, p=.055, 95\% \text{ CI } [0.002,0.17]$ . However, when the CS+ was accompanied by the social support figure image, we observed an inhibition of the conditional fear response, as evidenced by no SCR difference to the social support/CS+ compound vs. the CS-,  $t(19)=1.04, p>.250, 95\% \text{ CI } [-0.04,0.11]$  (Fig. 4). The effect of condition (social support, stranger, neutral secondary image) on inhibition, however, was not significant, possibly due to the smaller range of SCR seen during the summation stage,  $F(2,38)=1.35, p>.250, \eta_p^2=.046$ . Still, these results demonstrate that social support figure stimuli inhibit conditional fear responding, passing the summation test without any

lab-based training and satisfying the second test of a prepared safety stimulus as defined above.

In addition to these results, we also examined responses from the test stage of the experiment, in which the secondary image was removed and the response to the CS+ was re-examined. Specifically, there was still a significant conditional fear response (greater SCR to the CS+ vs. CS-) after taking away the neutral secondary image,  $t(19)=4.31$ ,  $p=.000$ , 95% CI [0.15,0.05], and the stranger secondary image,  $t(19)=3.19$ ,  $p=.005$ , 95% CI [0.12,0.02] (Fig. 5). However, when the social support figure secondary image was removed, there was no return of

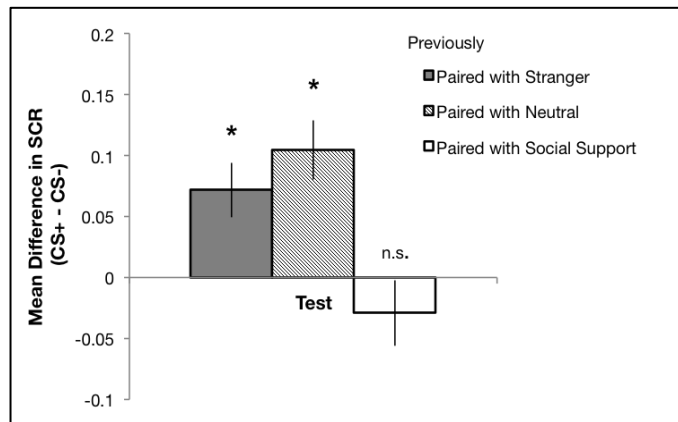
the conditional fear response,  $t(19)=-1.08$ ,  $p=.292$ , 95% CI [0.03,-0.08] (Fig. 5). Further examination of the effect of condition on return of fear demonstrated a significant effect,

$F(2,38)=9.48$ ,  $p=.000$ ,  $\eta_p^2=.333$ ,

such that there was significantly less return of fear after removing the social support stimulus

compared to removing the stranger,  $t(19)=-2.55$ ,  $p=.019$ , 95% CI [-0.18,-.02] or neutral stimulus,  $t(19)=-5.28$ ,  $p=.000$ , 95% CI [-0.19,-0.08].

Together with the results from Experiment 1, these findings support the hypothesis that social support figures act as prepared safety stimuli by showing that they



**Figure 5.** SCR from the test stage of Experiment 2. Conditional fear responses were evaluated by comparing the SCR for each CS+ that had been paired with a secondary image during the summation stage (stranger, neutral, social support) to the CS-. After the secondary images were removed and the original CS+s were once again presented alone, there was a conditional fear response to CS+s that had been paired with stranger and neutral stimuli, but not for the CS+s that had been paired with social support stimuli. Error bars indicate standard errors. Asterisks indicate a statistically significant difference score, and “n.s.” indicates non-significant.



pass both the retardation-of-acquisition and summation tests without any prior lab-based training. Moreover, social support figures appear to have longer-term effects on inhibiting fear responses even after the support stimuli are removed.

### **Experiment 3**

In order to ensure that the safety effects of social support figures were due to their value as social support figures and not other confounding factors, such as their familiarity or reward value, Experiment 3 used a retardation-of-acquisition procedure to examine whether it was also difficult to acquire a conditional fear response to familiar and rewarding stimuli.

#### **Method**

*Retardation-of-Acquisition Procedure.* For Experiment 3, in addition to asking participants to select two social support figures, we also asked them to identify: 1) stimuli that were high in familiarity but low in social support, namely two professors from courses they were currently enrolled in (and who they saw at least twice a week), and 2) stimuli that were high in reward value/positivity but low in social support, namely two of their favorite foods. For each selection, participants rated on a scale of 1-10: 1) how much social support this stimulus gives them everyday, 2) how familiar this stimulus is (would they recognize him/her walking down the street?/would they recognize it?), and 3) how positively they feel about this stimulus. As expected, results from these ratings showed that social support stimuli were rated highly on all 3 dimensions: received social support ( $m=9.20$ ), familiarity ( $m=9.95$ ), and positivity ( $m=9.63$ ). Familiar stimuli were rated highly in familiarity ( $m=8.50$ ) and positivity ( $m=7.35$ ), but lower in social support

( $m=4.33$ ). Rewarding stimuli were rated highly in positivity ( $m=9.35$ ) and familiarity ( $m=9.85$ ), but low in social support ( $m=2.37$ ) (see supplemental materials for further details).

Participants underwent a fear conditioning session with 3 sets of stimuli that were individually tailored to each participant: (1) two images of social support figures, (2) two images of professors, and (3) two images of favorite foods. The procedures were the same as those described for Experiment 1, except that for each stage of the experiment, each image was presented in a pseudorandom order for 6 seconds, followed by a 6 second ISI. Examination of data from the habituation stage revealed that within each condition, no pre-existing characteristics of the stimuli within any condition that led to heightened SCR ( $p's > .213$ ), indicating there were no pre-existing differences in the stimuli that created later differences in SCR.

*Analysis Strategy.* The same data analysis strategy as outlined for Experiment 1 was used to compare learned fear patterns across the 3 conditions in Experiment 3.

## **Results**

In order to determine whether familiarity or reward might be driving the prepared safety effects of social support figures demonstrated in Experiments 1 and 2, we examined whether conditional fear was acquired for familiar and rewarding stimuli, compared to social support stimuli. We found that conditional fear responses were acquired to both the familiar and rewarding stimuli. Specifically, there was significantly greater SCR to the CS+ compared to the CS- for both the familiar,  $t(19)=6.16$ ,  $p=.000$ , 95% CI [0.16,0.07] and rewarding stimuli,  $t(19)=2.91$ ,  $p=.011$ , 95% CI [0.17,0.03] (Fig. 6). However, replicating the pattern of effects found in Experiment 1, no conditional fear

response was acquired to the social support figure stimuli,  $t(19)=1.56, p=.141, 95\% \text{ CI } [0.09, -0.01]$  (Fig. 6).

Examination of the effect of condition

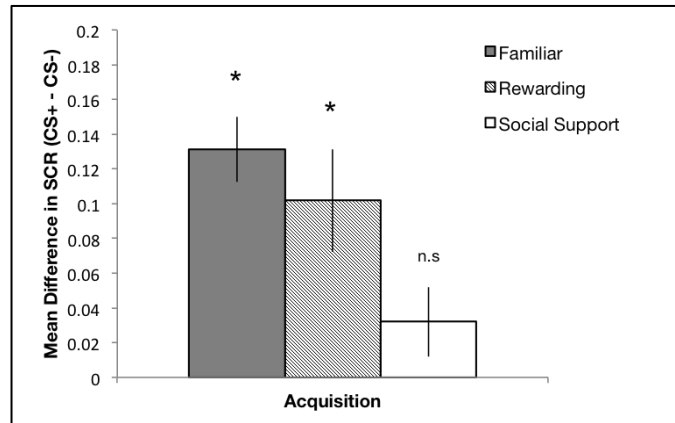
(familiar, rewarding, social support) on fear learning

revealed a significant effect,

$F(2,38)=4.65, p=.016, \eta_p^2=.197$ , such that fear acquisition in the social support condition was significantly reduced relative to fear acquisition in the familiar condition,  $t(19)=-3.49, p=.002, 95\% \text{ CI } [-0.16,-0.04]$ , and marginally reduced relative to the rewarding condition,  $t(19)=-1.92, p=.070, 95\% \text{ CI } [-0.15,0.01]$ .

## Discussion

Social bonds are crucial for survival, and therefore our social support figures may be one category of prepared safety stimuli—signaling protection from danger, reducing fear responding, and attenuating fear learning. However, little prior work has examined this. The present research explored whether social support figures are prepared safety stimuli by developing a definition of prepared safety stimuli based on Pavlovian Conditioning theory and testing whether social support figures fit the parameters of that definition. Results showed that social support figures passed both the retardation-of-



**Figure 6.** SCR from the retardation-of-acquisition test in Experiment 3. Conditional fear responses were evaluated by comparing the SCR for each CS+ to the CS- within each category (familiar, rewarding, social support). After acquisition, there was a conditional fear response to both familiar and rewarding stimuli, but not for social support stimuli. Error bars indicate standard errors. Asterisks indicate a statistically significant difference score, and “n.s.” indicates non-significant.

acquisition and summation tests, fulfilling the requirements of a conditioned inhibitor of the fear response without training in the lab.

Specifically, in Experiment 1, participants did not learn to associate the threat of shock with an image of their social support figure, although they could learn this association for images of strangers or neutral objects. In Experiment 2, we found that when a conditional fear stimulus was paired with a social support figure image, there was an inhibition of the fear response, while there was no inhibition of the fear response when paired with a stranger or neutral image.

In addition, results from Experiment 2 showed that pairing social support figures with a fearful cue during extinction led to a lasting inhibitory effect on the fear response. Interestingly, these results are at odds with the literature examining protection from extinction (Lovibond, Davis, & O’Flaherty, 2000; Lovibond et al., 2009; Rescorla, 2003), which shows that pairing a *learned* safety signal with a fearful cue during extinction leads to a return of fear-responding when the safety signal is removed, rather than reduced fear-responding, which was observed here. This discrepancy in findings may be due to the fact that prior studies have not examined prepared safety stimuli (or social support figures specifically). Thus, it is possible that prepared safety stimuli may have different effects on the return of conditional fear responses than learned safety stimuli, making this an important area of investigation.

Finally, in Experiment 3, we examined the possibility that the observed safety effects of social support stimuli were due to familiarity or reward. These results demonstrated that neither familiar others (current professors with whom students had frequent exposure) nor rewarding stimuli (favorite foods) passed the retardation-of-

acquisition test. Therefore, these categories of stimuli, although familiar and/or rewarding, do not naturally signal safety and would not fulfill the requirements of prepared safety stimuli.

Although it is possible that social support figures could simply be very well-learned conditioned inhibitors, as opposed to “prepared” safety stimuli, there are two findings that suggest that social support figures may operate differently than other learned safety signals and thus may be ‘prepared’ to act as safety signals. First, unlike conditioned inhibitors or well-learned safety signals, which, when present during extinction, lead to return of fear after being removed, the present data show that social support figures continue to inhibit the fear response even after being removed. Second, animal research has demonstrated that even animals raised by abusive caregivers show reduced threat responses when exposed to cues associated with those caregivers (Rainecki et al., 2015), indicating that even in cases where safety is not learned, such as with abusive caregivers, social support figures reduce threat responding.

Together, these results suggest that social support figures may indeed be one category of prepared safety stimuli. However, unlike prepared fear stimuli, for which the specific feared stimuli are thought to require no learning and to be universal (e.g., snakes, spiders), for social support figures as prepared safety stimuli, the *specific* support figures are learned and not universal (e.g., one social support figure will not have a safety association for all individuals). Hence, when referring to social support figures as prepared safety stimuli, the meaning is not that a *specific* person is a prepared stimulus (for everyone), but that the prepared stimulus is instead a placeholder, or “slot” in the attachment behavioral system, which may be occupied by certain close others who serve

as sources of social support. How a certain individual comes to occupy the prepared slot is unclear; however, recent work has suggested that feeling comforted by another following a period of distress might increase feelings of attachment and security (Beckes, Simpson, & Erickson, 2010). Additional research will help to clarify who can fill the prepared safety slot, and how they come to do so.

Regardless of the nature of the experience that endows an individual with these fear inhibitory properties, without doubt that experience is fundamentally different than the conditioning laboratory experience. Importantly, it is highly improbable that participants had prior experience with an electric shock unconditional stimulus. Despite this, the support stimulus's inhibitory properties transferred to this unique context. Given that the ability for inhibition to transfer even within a laboratory situation is often limited (Holland, 1991), this level of transfer is impressive.

While this work sheds light on the role of social support figures as prepared safety signals, more research must be conducted to examine the boundary conditions of these effects, such as the impact of the quality of the relationship with social support figures on their ability to function as prepared safety stimuli. Additionally, it would be beneficial to collect larger sample sizes in order to examine whether gender or certain individual differences (e.g., attachment style) play a role in the safety effects reported here.

The implications of these findings extend beyond fear learning for social support targets, and suggest consequences for learning fear to other cues as well. As the properties of prepared safety stimuli are, as of yet, unexplored, it is possible that these stimuli might impact the ways in which fear is learned and extinguished. Thus, due to their powerful safety signal value, prepared safety stimuli might: 1) buffer individuals

against forming fear associations to novel cues and 2) enhance extinction to fears learned to these novel cues. Future work is necessary to shed light on how prepared safety stimuli might alter basic fear learning processes.

To the extent that social support figures inhibit other types of fear learning, it suggests that conceptualizing social support figures as prepared safety stimuli might have important implications for understanding the links between social support and health. Research has consistently shown that individuals who have higher quality social relationships have better physical and mental health (Cohen, 1988; Cohen, 2004; Cohen et al., 1997; House, Landis, & Umberson, 1988; Thoits, 1995). Although the mechanisms underlying this relationship are unclear, one possibility is that social support figures, as prepared safety stimuli, reduce the learning of fear and enhance its extinction across various domains, ultimately reducing stress-related physiological reactivity, which may have implications for health. Future work will be needed to explore this possibility.

Altogether, the findings discussed here demonstrate that social support figures are powerful safety signals that not only do not require in-lab training to inhibit the fear response, but can also potentially lead to more lasting inhibition or extinction of fears—suggesting that social support figures may be one category of prepared safety stimuli. While further research is required, these results reveal some of the possible characteristics of stimuli in the prepared safety category and offer insight into the ways in which these stimuli might play adaptive and beneficial roles in daily life.

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## SUPPLEMENTAL MATERIALS

### **Materials and Method**

#### *Overall Procedures*

**Telephone Screening Session.** Participants were screened out if they were pregnant, had a history of mental illness or were currently taking any mental health related medication.

**Pre-screening Session.** Before the experimental session, participants came to the lab for a 30 minute pre-screening session during which they were tested to ensure that their Skin Conductance Response (SCR) could be detected by the experimental equipment. SCR for all experiments was measured using a BioPac MP100 system with EDA Isotonic Gel Electrodes, and data were collected and analyzed using AcqKnowledge 3.9 software (BioPac Systems, Inc., Aero Camino Goleta, CA, 93117). In order to perform the equipment test, electrodes were placed on the palmar side of participants' medial phalanges on the forefingers and middle fingers of their left hands. Participants were then asked to breathe in deeply, an action that causes activation of the sympathetic nervous system and consequent increases in SCR, and their responses were monitored to ensure that a SCR increase was detected. Only those participants whose responses were detected by the equipment were included in the experiment.

While this procedure did exclude some individuals from participating based on their SCR, leading to potential biases in the data, it allowed us to remove individuals who were low responders (and who would likely have later been excluded from data analysis).

**Experiment Session.** At the beginning of the experimental session, participants underwent an electric shock calibration procedure to determine the appropriate level of

shock to be applied during the experiment. Shock was delivered to the subject via a bar lead electrode placed on the right wrist, and was triggered from a SD9 Pulse Stimulator from Grass Technologies (Natus Neurology, Inc. – Grass Products, Middleton, WI, 53562). During the shock calibration procedure, participants were exposed to 200ms electric shocks beginning at 30 volts, which increased by 5 volt increments. Participants were told to alert the experimenter when the shock was extremely uncomfortable, but not yet painful. This work up procedure was designed based on the work up procedure used in previous studies that employ shock for human fear conditioning (see: Olsson, Ebert, Banaji, & Phelps, 2005; Phelps, Delgado, Nearing, & LeDoux, 2004; Schiller, Monfils, Raio, Johnson, LeDoux, & Phelps, 2010). Average voltage (as decided upon by the experimenter and the participant during the shock calibration procedure) was 50.75 volts for Experiment 1, 51.125 volts for Experiment 2, and 47.00 volts for Experiment 3.

All stimuli were presented using E-Prime 2.0 software (Psychology Software Tools, Inc., Sharpsburg, PA, 15215).

### *Data Analysis*

The target sample size for each Experiment was  $n = 20$ . Thus, for each Experiment, participants were recruited until we had 20 usable participants for that particular study.

**Participants.** *Experiment 1.* A total of 41 participants were recruited. Three participants were excluded based on exclusion criteria from the telephone screening (i.e. had a history of mental illness, were taking mental health related medication or were possibly pregnant), 4 were excluded due to no detectable SCR during the pre-screening

session, 4 were excluded due to equipment malfunction, and 10 were excluded due to not acquiring a conditional fear response to at least one CS+ after the acquisition stage of the experiment (likely indicating a lack of attention or unawareness of CS-US contingencies, see Dawson & Shell, 1985).

*Experiment 2.* A total of 65 participants were recruited. Two were excluded based on exclusion criteria from the telephone screening, 13 were excluded due to no detectable SCR during the pre-screening session, 3 had no detectable SCR at the beginning of the experiment session, 1 dropped out, and 26 were excluded due to not acquiring a conditional fear response to all three CS+'s during the acquisition stage of the experiment. This was done to ensure that a conditional fear response was acquired to each CS+ before examining whether each secondary image could inhibit the conditional fear response during the summation stage of the experiment.

*Experiment 3.* A total of 30 participants were recruited. Two were excluded based on exclusion criteria from the telephone screening, 3 were excluded due to no detectable SCR during the pre-screening session, 2 dropped out, and 3 were excluded due to being low responders (displayed SCRs on fewer than 25% of the trials throughout the acquisition session). All participants acquired fear responses to the CS+ (SCR for CS+ > CS-) in at least one condition.

For both experiments, guidelines for sample size and participant exclusion were based on exclusion criteria used in prior human fear conditioning studies (see: Olsson, Ebert, Banaji, & Phelps, 2005; Schiller, Monfils, Raio, Johnson, LeDoux, & Phelps, 2010).

**Pre-processing.** SCR Data collected with AcqKnowledge was pre-processed using a low pass filter and smoothed. Data was then evaluated using peak-to-peak analysis for each trial (each image presentation)—the peak-to-peak amplitude was measured in micro-siemens ( $\mu\text{S}$ ) for the largest response that occurred between .5s-4.5s after stimulus onset (these methods were chosen based on recommendations for SCR analysis, see: Figner & Murphy, 2011). These measurements were then normalized using a square-root transformation.

During any trial, if there was no peak (no rise in SCR during the .5-4.5s stimulus window), then the trial was scored as a zero response trial. Additionally, a .02  $\mu\text{S}$  threshold was implemented for peak-to-peak amplitudes, such that if the peak-to-peak amplitude for any trial was below .02  $\mu\text{S}$ , the trial was scored as a zero response trial. If there was movement during a trial, as recorded by the experimenter during the experimental session, that trial was excluded from data analysis.

For experiments 2 and 3, if participants displayed SCR responses on fewer than 25% of the acquisition trials they were considered low responders and their data was excluded from the analysis (see above). This resulted in the exclusion of 3 participants from experiment 3 (none were excluded based on this criterion in experiment 2). For experiment 1, if participants displayed SCR responses on fewer than 15% of the acquisition trials they were considered low responders and their data was excluded from the analysis. This change was employed due to the use of the first two trials of the extinction stage as a measure of acquisition. No participants were excluded from analysis based on this criterion.

**Scoring.** *Experiment 1.* The habituation mean was calculated by averaging across all habituation trials. Acquisition was examined by comparing the SCR from the first two presentations of each stimulus after the acquisition stage was completed (the first two presentations of each stimulus during the extinction stage), chosen in order to examine fear expression for the CS+'s after the fear acquisition procedures were completed (based on fear expression tests used in previous animal literature, see: Fanselow & Baackes, 1982; Kiyokawa, Takeuchi, & Mori, 2007; Newton, Ellsworth, Miyakawa, Tonegawa, & Sur, 2004). If the acquisition mean for the CS+ was not greater than that of the CS- (CS+ - CS- > 0) or if there were no peaks occurred during these trials, the participant was considered not to have acquired conditional fear for that condition.

It is important to note that although the current manuscript reports results using the first two trials of the extinction stage as a measure of fear acquisition, these results do not change if we simply use the first trial of the extinction stage. Thus, if we use the first trial of the extinction stage we find the same pattern of results, with fear being acquired for the stranger,  $t(19)=2.63$ ,  $p=.017$ , 95% CI [0.30,0.03], and neutral,  $t(19)=2.31$ ,  $p=.032$ , 95% CI [0.17,0.01] conditions, but not in the social support condition,  $t(19)=1.23$ ,  $p=.235$ , 95% CI [-0.05,0.19]. Additionally, a similar pattern of results was seen when comparing learning across conditions,  $F(2,38)=4.72$ ,  $p=.015$ ,  $\eta_p^2=.199$ , with reduced learning occurring in the social support condition compared to the stranger condition,  $t(19)=-2.89$ ,  $p=.009$ , 95% CI [-0.41,-0.07], and neutral condition,  $t(19)=-2.34$ ,  $p=.031$ , 95% CI [-0.30,-0.02].

*Experiment 2.* The habituation mean was measured by averaging across all habituation trials. The acquisition mean was measured by averaging across the last 3

presentations for each CS+ and the last 7 presentations of the CS- during the acquisition stage (roughly the last 75% of the presentations for each stimulus type), chosen in order to determine if learning had occurred for the three CS+'s beginning after the first image-shock pairing. If the acquisition mean for the CS+ was not greater than that of the CS- ( $CS+ - CS- > 0$ ) or if there were no peaks occurred during these trials, the participant was considered not to have acquired conditional fear for that condition. The summation mean was measured by averaging across the first two presentations of each stimulus during the summation stage of the experiment, chosen in order to measure levels of inhibition across multiple trials without including later trials, during which some extinction learning might have occurred or new CS+/secondary image-US contingencies might have been formed. Fear expression during the test stage was examined by comparing the SCR during the first two presentations of each CS+ and the first two presentations of the CS- during the test stage (test stage means), chosen in order to remain consistent with the way in which we have reported results for the other studies.

It is important to note, that although the current manuscript reports results using the first two trials of the test stage as a measure of fear expression, these results do not change if only the first trial of the test stage is used. Thus, if we use simply the first trial of the test stage we find the same pattern of results, with a fear response being present for the stranger,  $t(19)=3.68$ ,  $p=.002$ , 95% CI [0.06,0.23], and neutral,  $t(19)=3.87$ ,  $p=.001$ , 95% CI [0.08,0.27], conditions, but not in the social support condition,  $t(19)=-.462$ ,  $p>.250$ , 95% CI [-0.13,0.08]. The ANOVA also shows a similar pattern of results,  $F(2,38)=6.29$ ,  $p=.004$ ,  $\eta_p^2=.249$ , with less return of fear occurring in the social support



condition compared to the stranger,  $t(19)=-2.21$ ,  $p=.040$ , 95% CI [-0.33,-.01], or neutral,  $t(19)=-3.91$ ,  $p=.001$ , 95% CI [-0.30,-0.09], conditions.

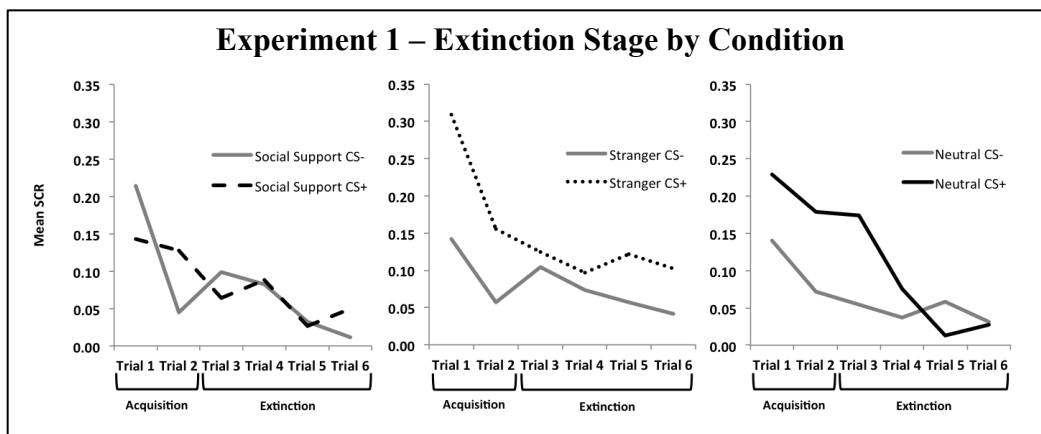
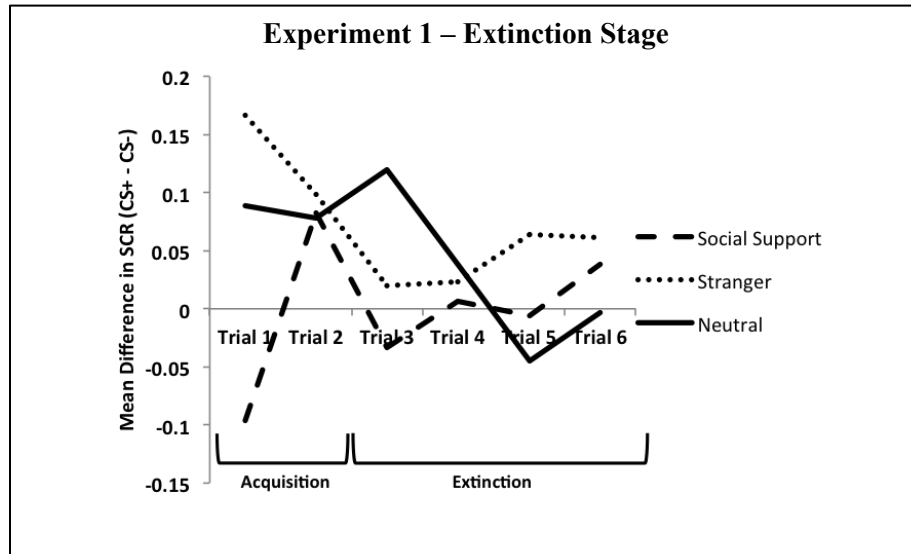
*Experiment 3.* The same data scoring strategy employed in Experiment 1 was used for Experiment 3, with the following exception. Acquisition means were now taken from the acquisition stage (calculated using the final 4 trials for each stimulus presentation). This was done in order to confirm that the fear learning patterns examined using the first two trials of extinction in Experiment 1 were consistent with fear acquisition patterns exhibited at the end of the acquisition stage in Experiment 3. If the acquisition mean for the CS+ was not greater than that of the CS- ( $CS+ - CS- > 0$ ) or if there were no peaks occurred during these trials, the participant was considered not to have acquired conditional fear for that condition.

### **Additional Analyses and Data**

#### *Experiment 1*

**SCR.** Paired samples t-tests were run comparing the habituation means for the future CS+ to the future CS- from each condition. We found that there were no significant differences in SCR for the CS+ vs. CS- from any of the 3 conditions, verifying that there were no pre-existing characteristics of any of the stimuli that led to more arousal: neutral  $t(19)=-0.882$ ,  $p=.389$ , 95% CI [0.03, -0.04], stranger,  $t(19)=-0.116$ ,  $p=.909$ , 95% CI [0.01, -0.03] social support,  $t(19)=0.913$ ,  $p=.373$ , 95% CI [0.04, -0.01].

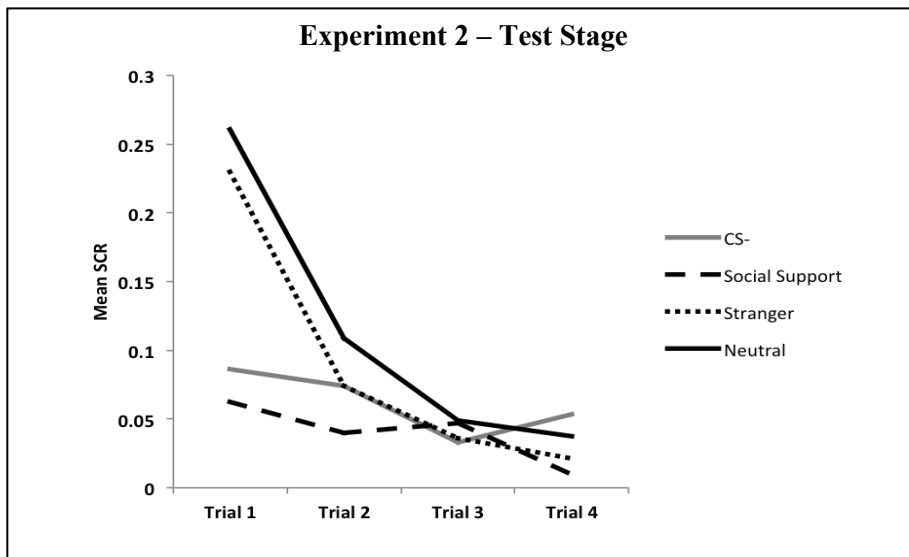
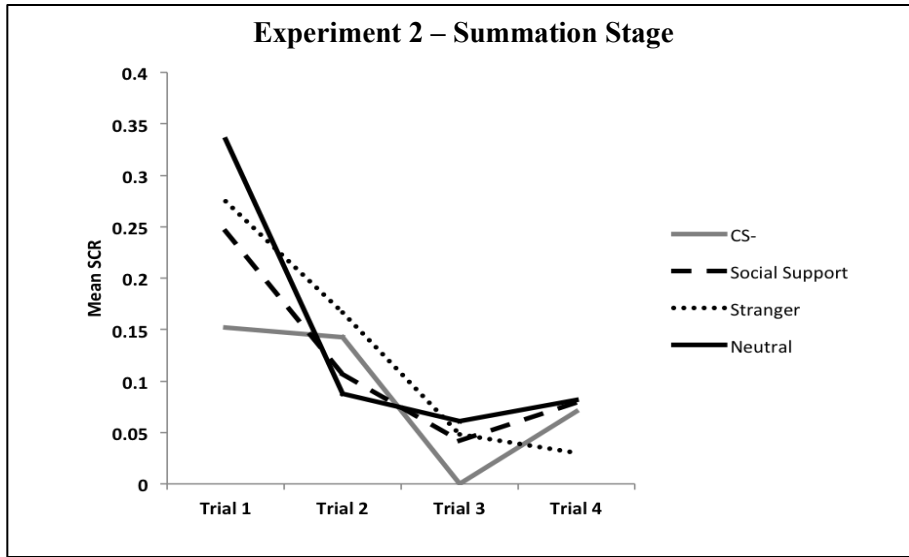
#### **Trial-by-trial SCR.**



## Experiment 2

**SCR.** Paired sample t-tests were run comparing the habituation means for each of the future CS+'s to the future CS-. We found that there were no significant differences for the mean SCR score for each of the three CS+'s compared to that of the CS-, verifying that there were no pre-existing characteristics of any of the stimuli that led to more arousal: neutral,  $t(19)=0.086$ ,  $p=0.932$ , 95% CI [-0.03,0.04], stranger,  $t(19)=-0.882$ ,  $p=.389$ , 95% CI [-0.03,0.01], social support,  $t(19)=0.334$ ,  $p=.742$ , 95% CI [-0.03,0.05].

### Trial-by-trial SCR.



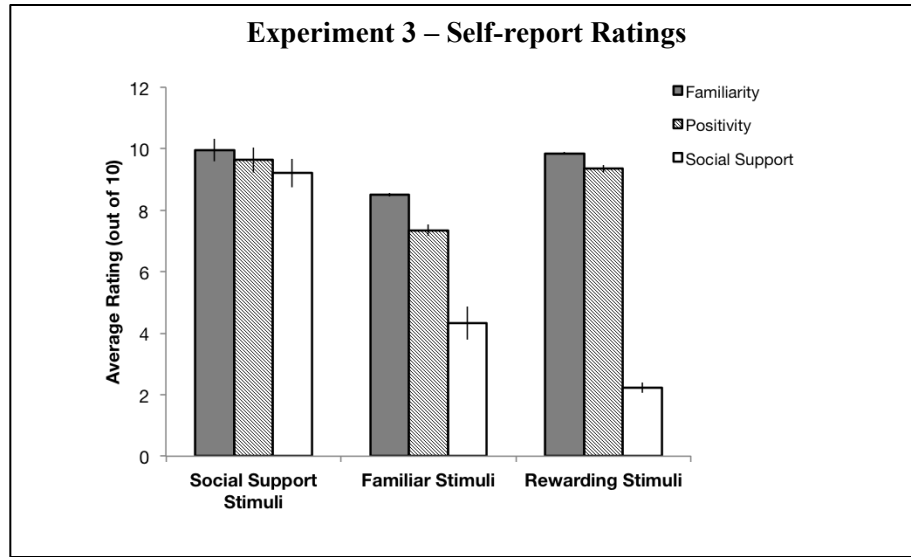
### Experiment 3

#### Self-report Data.

Comparing across the 3 sets of stimuli, we found that all 3 sets of stimuli were rated as being high in familiarity; however, social support figures and favorite foods, while not rated differently from each other ( $t(19)=1.45, p=.163, 95\% \text{ CI } [-0.04, 0.24]$ ) were rated as more familiar than current professors (vs. social support stimuli:

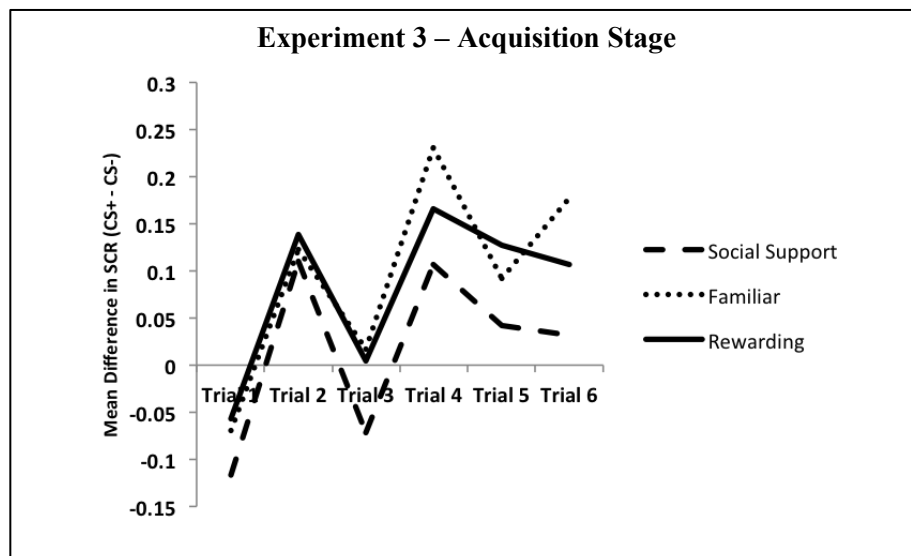
$t(19)=4.24, p=.000, 95\% \text{ CI } [0.73,2.16]$ , vs. rewarding stimuli:  $(19)=3.796, p=.001, 95\% \text{ CI } [0.61,2.09]$ ). Both social support figures and rewarding stimuli were rated as being high in positivity (no difference;  $t(19)=1.47, p=.157, 95\% \text{ CI } [-0.12,0.67]$ ) and were significantly higher in positivity than familiar professors (vs. social support stimuli,  $t(19)=5.58, p=.000, 95\% \text{ CI } [1.42,3.12]$ ; vs. rewarding stimuli:  $t(19)=4.55, p=.000, 95\% \text{ CI } [1.08,2.92]$ ). Importantly, only social support figures were rated as being high in received social support and these ratings were higher than the ratings reported for the familiar ( $t(19)=10.66, p=.000, 95\% \text{ CI } [3.92,5.83]$ ) and rewarding ( $t(15)=12.21, p=.000, 95\% \text{ CI } [5.65,8.04]$ ) stimuli.

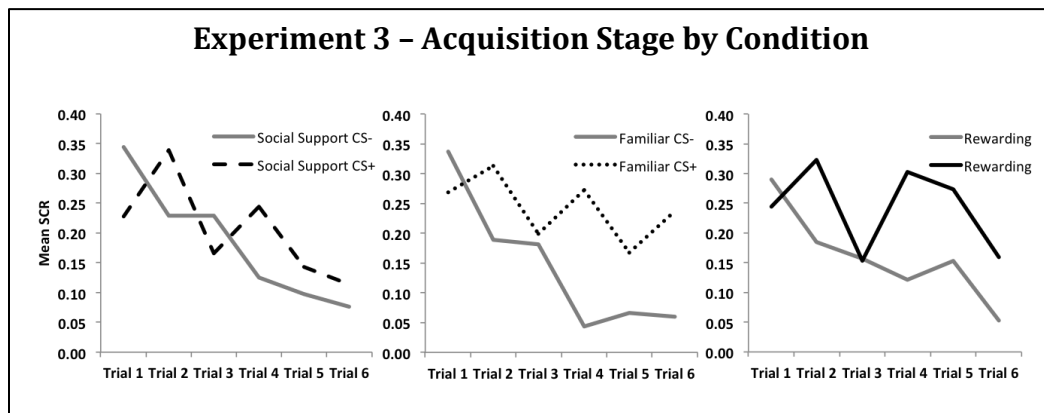
Based on these subjective responses to the three conditions, we would expect that, to the extent that the support value of social support figures is driving the safety effects, subjects should only be unable to acquire fear to the social support figures. Alternatively, to the extent that the reward value of social support figures is driving the effects, we should find that subjects should be unable to acquire fear to both the social support and rewarding stimuli. Finally, to the extent that familiarity is driving the effects, we should find that subjects should be unable to acquire fear to the social support and rewarding stimuli.



**SCR.** Paired samples t-tests were run comparing the habituation means for the future CS+ to the future CS- from each condition. We found that there were no significant differences in SCR for the CS+ vs. CS- from any of the 3 conditions, verifying that there were no pre-existing characteristics of any of the stimuli that led to more arousal: familiar  $t(19)=0.439$ ,  $p=.666$ , 95% CI [-0.05,0.03], rewarding,  $t(19)=-0.285$ ,  $p=.779$ , 95% CI [-0.03,0.04] social support,  $t(19)=-1.29$ ,  $p=.213$  95% CI [-0.01,0.05].

**Trial-by-trial SCR.**





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Paper 2:

Prepared safety as a buffer: The effect of social support on fear acquisition

Erica Anne Hornstein & Naomi Ilana Eisenberger

## ABSTRACT

Social support is known to be linked to positive health outcomes, and research has demonstrated that the presence, or even just a reminder, of a social support figure can reduce psychological and physiological responses to threats. However, no previous work has examined the impact of social support on fear learning for other cues. This study examined whether social support figures, who have been shown to be powerful natural safety signals, inhibit the formation of fear associations with other neutral cues. After conducting a fear conditioning procedure in which social support stimuli were paired with conditional stimuli during fear acquisition, we found that the threat of shock was not associated with conditional stimuli that were paired with images of social support figures, while the threat of shock was associated with stimuli that were paired with images of strangers. These findings indicate that social support may prevent the formation of fear associations, reducing the amount of learned fears people acquire as they navigate the world, consequently reducing threat-related stress.



Research has consistently demonstrated a relationship between social support and positive health outcomes. It has been suggested that these health advantages arise because social support provides a buffer for individuals when dealing with life stress, and findings have shown that social support buffers against both the psychological and physiological threat response. However, little prior work has examined the mechanisms whereby social support reduces physiological or psychological responses to threat. The present research seeks to explore this relationship by testing whether social support inhibits the formation of fear associations, consequently reducing fear responding and threat-related stress.

Within the social buffering literature, it has been shown that individuals who have larger social networks, higher quality social relationships, and more access to social support resources have better physical and mental health, enjoying advantages ranging from a lower susceptibility to the common cold to a decreased risk of disease and death (Cohen, Doyle, Skoner, Rabin, & Gwaltney 1997; Cohen, Doyle, Turner, Alper, & Skoner, 2003; House, Landis, & Umberson, 1988). It has been suggested that these positive health outcomes stem, in part, from the buffer social support provides, buoying individuals as they deal with life stress. However, this literature focuses on establishing the impact of social support as a buffer, while the process by which social support provides this buffer remains not well understood.

Evidence for this stress-buffering hypothesis can be found in both the animal and human literatures, and findings demonstrate that social support reduces both the psychological and physiological impact of threats. Animal research has shown that that the presence of familiar or close others decreases both the amount of escape and avoidance behavior exhibited in threatening contexts (Hall, 1955; Baum, 1969),

decreases the amount of freezing behavior in response to a known threat (Davitz & Mason, 1955), increases the ability to tolerate new environments (Liddell, 1950; Liddell, 1954), and decreases the amount of anxious behaviors exhibited following an experience of social defeat (Ruis, et al., 1999; Nakayasu & Ishii, 2008; Nakayasu & Kato, 2011). In addition to reducing behavioral and emotional stress responses, the presence of a familiar other can ameliorate physiological stress responses in the face of threatening events or situations. For example, the presence of a member of the same species with whom there is a bond reduces levels of cortisol when guinea pigs experience novel environments (Sachser, Durschlag, & Hirzel, 1998; Hennessy, Zate, & Maken, 2008).

Consistent with the animal research on social buffering, work with humans has demonstrated that social support provides a similar buffering effect in threatening or stressful contexts. Findings show that perceptions of strong social support systems or relationships lead to reduced psychological stress in response to negative events (Cohen & Hoberman, 1983; Cohen & McKay 1984; Kessler & McLeod, 1985). Moreover, having higher levels of reported daily social support is correlated with reduced cortisol levels when faced with social stressors (Eisenberger, Taylor, Gable, Hilmert, & Lieberman, 2007) as well as reduced heart rate and blood pressure in the face of acute stressors (Gerin, Pieper, Levy, & Pickering, 1992; Thorsteinsson, James, & Gregg, 1998; Thorsteinsson & James 1999). Additionally, it has been demonstrated that social support can provide a buffer for individuals by mitigating the experience of pain (Brown, Sheffield, Leary, and Robinson, 2003; Master, et al., 2009; Younger, Aron, Parke, Chatterjee, & Mackey, 2010). Recent work suggests that this pain-mitigating effect may be due to decreased activity in neural regions associated with the distressing aspect of

pain and increased activity in neural regions associated with safety (Eisenberger, et al., 2011). Altogether, these findings point to the important role played by social support in regulating stress in the face of threat, leading to lower behavioral and physiological reactivity, and possibly resulting in fewer negative downstream health consequences.

One possible mechanism by which social support provides this buffer against stress is by acting as a powerful natural safety signal—communicating protection from threats and consequently reducing psychological and physiological threat responses. Indeed, recent research has shown that social support figures are one category of prepared safety stimuli, less easily becoming associated with threat and reducing conditional fear responses, and that the presence of social support figure reminders potentially leads to longer lasting fear extinction (Hornstein, Fanselow, & Eisenberger, in press). Thus, by signaling safety and interfering with normal fear learning processes, social support may reduce threat-related stress and increase positive health outcomes.

However, to date, no work has been done to examine the effect of social support on the way fear is learned for other events or stimuli in the environment. It is possible that social support not only signals safety and reduces fear responding, but also decreases the amount of fear associations that people form overall. A better understanding of this function of social support would both provide insight into the link between social support and reduced stress and shed light on possible social support interventions that can be used to boost positive health outcomes. Therefore, we designed a study to examine the impact of social support on fear learning, examining the effect of social support figure stimuli on the association of threat with other cues and testing whether social support buffers individuals against acquiring new fears.

In order to test the impact of social support on fear learning, we conducted a fear conditioning paradigm to examine whether the presence of social support figure stimuli, defined here as the individual from whom a participant receives the most social support (in the form of care and resources) on a daily basis, reduced fear acquisition for a separate neutral cue. Specifically, we assessed conditional fear responses when a social support figure's image, or a stranger's image, was paired with a neutral cue during fear acquisition. We hypothesized that while a conditional fear response would be acquired for neutral stimuli paired with images of strangers, no conditional fear response would be acquired for neutral stimuli paired with images of social support figures.

## **Method**

*Participants.* Data were analyzed from a final sample of 20 participants (*mean age*= 19.70, 15 *females*) who completed the study procedures. In total, 30 participants were recruited, 2 participants were excluded based on the telephone screening, 4 participants were excluded based on the SCR screening, and 4 participants were excluded due equipment malfunction. All participants were recruited from the University of California, Los Angeles community, and all experimental procedures were approved by the University of California, Los Angeles Institutional Review Board.

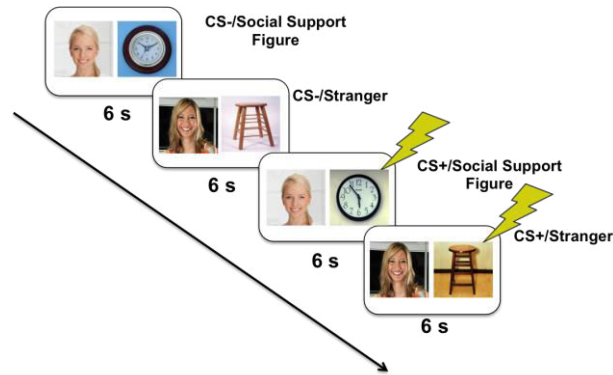
*Procedure.* The study had three parts: a telephone screening, a pre-screening session in the lab, and the experiment session. Participants first completed the telephone screening session and a pre-screening session to determine if they were eligible to participate in the experimental session (see supplemental materials). During the pre-screening session, they were asked to select “the individual who gives you the most

support on a daily basis” and to rate how much social support this individual gives everyday on a scale of 1-10 (mean rating=8.60). They were then instructed to send a digital photograph of this individual to the experimenter before the experiment session.

For the experiment session, participants returned to the lab and first completed a shock calibration procedure in order to determine the level of shock to be used for each individual participant during the experiment, such that it was extremely uncomfortable, but not painful (see supplemental materials). Participants then underwent a fear conditioning session with 2 sets of stimuli. Each set comprised 2 neutral images from one of two object categories (clocks, stools), which were paired with a secondary image (social support figure, stranger) during the acquisition stage of the experiment. One neutral image from each set was a CS+ and one was a CS-, and both were paired with the *same* secondary image during acquisition. There were three stages of the experiment: Habituation, Acquisition, and Extinction. For each stage, images were presented for 6 seconds, followed by a 10 second inter-stimulus interval in a pseudo-random presentation order that was counter-balanced across participants. Fear responses were evaluated using Skin Conductance Response (SCR) measurements.

During the Habituation stage of the experiment, participants saw 3 non-reinforced presentations of each neutral image. This was done in order to ensure that there were no pre-existing characteristics of either of the neutral stimuli in each set that might account for later differences in SCR, and none were found (comparing the future CS+ to the future CS- in the social-support paired condition,  $t(19)=-0.77, p=.451$ , 95% CI[-0.07,0.03], and the stranger paired condition,  $t(19)=1.34, p=.195$ , 95% CI[-0.01,0.05]).

Following this, there was the Acquisition stage (see Fig. 1), during which participants viewed six presentations of the images from each set paired with one of two secondary images: the social support figure image provided by the participants, or an image of a stranger that was gender, age, and ethnicity matched to the social support figure. One of the



**Figure 1.** Example of the CS/secondary image and shock pairings presented during the acquisition stage of the experiment. Participants viewed two sets of two neutral images (clocks, stools), and both images from each set were paired with the same secondary image (social support figure, stranger). One of these pairings from each set was paired with shock, the CS+/secondary image pairing, and one pairing was never paired with shock, the CS-/secondary image pairing. Following acquisition, there was an extinction stage (not shown here), during which each neutral image was once again presented on its own (no secondary image). Conditional fear acquisition was measured by comparing SCR for the CS+/secondary image pairing to the CS-/secondary image pairing within each set of neutral images.

CS/secondary image pairings from each set was consistently presented (100% reinforcement schedule) with a co-terminating 200ms electric shock, and this was the CS+/secondary image pairing, while the other CS/secondary image pairing was never paired with shock, and this was the CS-/secondary image pairing. After the Acquisition stage, participants had a short break during which they viewed a video clip about airplanes. Finally, during the extinction stage, there were six non-reinforced presentations of each of the four original neutral images once again presented on their own, with the secondary image removed.

*Data Analysis Strategy.* In order to examine fear acquisition, paired-samples t-tests were run comparing acquisition means for the CS+/secondary image pairing to the CS-/secondary image pairing in the social support-paired and stranger-paired conditions. If the SCR aroused by the CS+/secondary image pairing was significantly higher than

that of the CS-/secondary image pairing, it was considered that a conditional fear response was acquired. Paired-samples t-tests were also run on the SCR aroused by the neutral images during the first trial of the extinction stage—the first trial after the secondary image had been removed and each neutral image was presented alone once again.

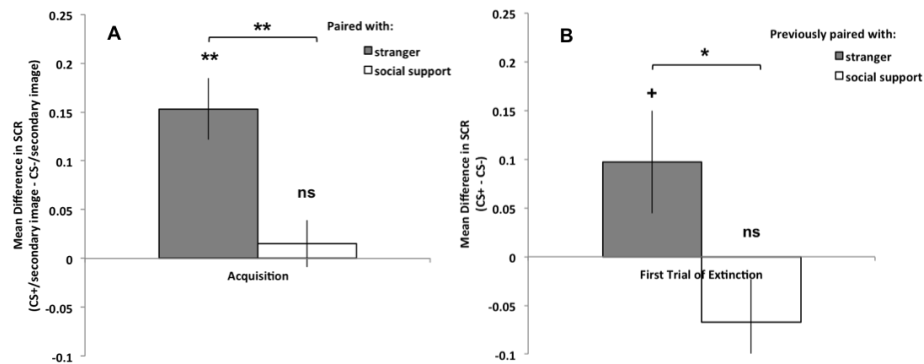
Additionally, we ran paired-samples t-tests to evaluate the effect of condition (social support-paired or stranger-paired) on fear acquisition, comparing mean difference scores (CS+/secondary image vs. CS-/secondary image within each condition). Similarly, we ran paired-samples t-tests to evaluate fear responses post-acquisition, comparing SCR difference scores (CS+ vs. CS- from each condition) from the first trial of extinction.

## **Results**

In order to determine the effect of the presence of a social support image during fear acquisition, we evaluated fear acquisition for both the social support-paired and the stranger-paired conditions. We found that while participants did acquire fear for CS+s paired with strangers,  $t(19)=4.86, p<.001, 95\% \text{ CI}[0.09,0.22]$ , they did not acquire fear for CS+s paired with social support figures,  $t(19)=.626, p=.539, 95\% \text{ CI}[-0.03,0.06]$ , (see Fig. 2a). Further examination showed that the effect of condition on fear acquisition was significant,  $t(19)=-3.80, p=.001, 95\% \text{ CI}[-0.21,-0.06]$ , such that fear acquisition in presence of a social support figure image was significantly less than fear acquisition in the presence of a stranger image.

In addition, we found that even after the secondary images were removed, a fear response was still present in the stranger-paired condition,  $t(19)=1.84, p=.082, 95\% \text{ CI}[-$

0.01,0.21], but there was no fear response present in the social support-paired condition,  $t(19)=-1.52, p=.144, 95\% \text{ CI}[-0.16,0.02]$  (see Fig. 2b). Moreover, examination across conditions revealed that the fear response was significantly less in the social support-paired condition than in the stranger-paired condition,  $t(19)=-2.28, p<.05, 95\% \text{ CI}[-0.31,-0.01]$ .



**Figure 2. A).** SCR from the Acquisition stage: conditional fear responses were evaluated by comparing the CS+/secondary image to the CS-/secondary image from each condition (social support-paired, stranger-paired). A conditional fear response was acquired in the stranger-paired condition, but not in the social support-paired condition. **B).** SCR from the first trial of the Extinction stage: conditional fear responses were evaluated by comparing the CS+ and CS- from each condition when once again presented alone (with the social support or stranger image removed). A marginal conditional fear response was still present for the CS+ that had been paired with a stranger image, but not for the CS+ that had been paired with a social support figure image. All error bars indicate standard error. Asterisks indicate a statistically significant difference score (\*\* indicates  $p < \text{or} = .001$ , \* indicates  $p < .05$ ), “+” indicates a marginal difference score ( $p < .1$ ), and “ns” indicates a non-significant difference.

## Discussion

Social support has long been linked to positive health outcomes. One explanation for these health benefits is that social support buffers individuals against life stress, and it has been demonstrated that the presence of social support reminders reduce both psychological and physiological responses to threat. To date, however, no research has examined the relationship between social support and fear learning for other cues. In the current research, we examined whether social support not only signals safety and inhibits the fear response, but also reduces fear associations formed for other neutral cues. Results



showed that the presence of social support reminders inhibits the formation of fear associations. Specifically, we found that when an image of a social support figure was paired with a neutral cue during fear acquisition, participants did not form a fear association for that cue, although they did form this association for a neutral cue paired with a stranger's image.

Additional results showed that when presented alone after fear acquisition was completed, a fear response remained for the neutral cue that had been paired with a stranger's image, but there was none for the neutral cue that had been paired with a social support figure's image, indicating that the benefits of social support continue even after an aversive event is over or a stressor is removed. This is interesting given that social integration, (participation in and a sense of belonging to a social network) has been shown to promote positive health outcomes even in the absence of current stress (for a review, see: Cohen, 2004). The current findings may give insight into the process underlying this effect—individuals with stronger social ties form fewer fear associations, while those who lack social ties form more fear associations that result in increased fear responding and stress as they interact with the world.

This reduction in fear learning may stem from the ability of social support stimuli to naturally, without any specific training, signal safety. It is possible that other characteristics of close others, such as being familiar or rewarding, could explain these effects. This is unlikely, however, given previous findings showing that while fear can be acquired for familiar or rewarding stimuli, it cannot be acquired for social support stimuli (Hornstein et al., in press); nonetheless, future research is required to definitively rule out this possibility. In addition, more work is required to identify the boundaries of social

support as a buffer against fear learning. For example, investigating whether this effect is found when the conditional stimuli used are more fear-relevant, such as with prepared fear stimuli, or whether this effect is found in participants who are more prone to developing fears, such as anxious individuals. Future research should also include exploration of other stimuli that might reduce fear associations, such as the experience of physical warmth, which has been shown to rely on the same neurological and neurochemical pathways as the experience of social warmth (Inagaki & Eisenberger, 2013; Inagaki, Irwin, & Eisenberger, 2015). Overall, further clarification of these effects will help to develop a better understanding of how and when social support interferes with fear learning, bolstering positive health outcomes.

Altogether, these findings build on previous research demonstrating the buffering effects of social support and reveal a clearer picture of how social support might reduce psychological and physiological stress. By inhibiting the formation of fear associations for other events, our close relationships may allow us to navigate the world with fewer learned fears, thus decreasing the activation of the threat response. Together with previous findings showing that social support figures fulfill the requirements of prepared safety stimuli (Hornstein, et al., in press), these results suggest that social support, and social support figures, may be helpful in preventing the formation of unnecessary or maladaptive fear associations and reducing threat related stress.

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## SUPPLEMENTAL MATERIALS

### **Materials and Methods**

#### *Screening and Procedures*

**Telephone Screening Session.** After a telephone screening with the experimenter, participants were not allowed to participate if they were pregnant, had a history of mental illness, or were currently taking any mental health related medication.

**Pre-screening Session.** If they passed the telephone screening, participants were asked to come into the lab for a 30-minute pre-screening session. During this session, participants were tested to ensure that their Skin Conductance Response (SCR) could be detected by the equipment being used for the experiment. SCR for all participants was measured using the BioPac MP100 system with EDA Isotonic Gel Electrodes, and data were collected using AcqKnowledge 3.9 software (BioPac Systems, Inc., Aero Camino Goleta, CA). For the test, and the following experiment session, electrodes were placed on the palmar side of participants' medial phalanges on the fore and middle fingers of the left hand. In order to activate the sympathetic nervous system and consequent increases in SCR, participants were asked to breathe in deeply, allowing the experimenter to monitor their responses and determine if an SCR increase was detected. If a participant's response was not detected by the equipment, he or she was excluded from the experiment.

**Experiment Session.** At the beginning of the experiment session, an electric shock calibration procedure was conducted to determine the appropriate level of shock to be applied for each individual participant during the experiment. Electric shock was applied to participants via a bar lead electrode placed on the write wrist, and was delivered from a SD9 Pulse Stimulator from Grass Technologies (Natus Neurology, Inc.

– Grass Products, Middleton, WI). For the shock calibration procedure, and during the experiment session, participants were exposed to a 200ms electric shock starting at 30 volts, and increasing in 5-volt increments. Participants were instructed to inform the experimenter when the shock became extremely uncomfortable, but was not yet painful, and that level of shock was then used during the experiment session. This work-up procedure was used previously (see: Hornstein, Fanselow, & Eisenberger, in press) and was designed based on work-up procedures from previous studies in which shock was used as an aversive stimulus during human fear conditioning (see: Olsson, Ebert, Banaji, & Phelps, 2005; Phelps, Delgado, Nearing, & LeDoux, 2004; Schiller, Monfils, Raio, Johnson, LeDoux, & Phelps, 2010). Average voltage (as decided upon by the experimenter and the participant during the shock calibration procedure) was 49.87 volts.

All stimuli were presented using E-Prime 2.0 software (Psychology Software Tools, Inc., Sharpsburg, PA).

### *Data Analysis*

**Participants.** The target sample size for the experiment was  $n=20$ , therefore participants were recruited until the targeted sample size was achieved. Target sample size and exclusion criteria, as described above, were based on guidelines from previous human fear conditioning studies (see: Hornstein, et. al., in press; Olsson, et. al., 2005; Schiller, et. al., 2010).

**Pre-processing.** All SCR data were collected and pre-processed using AcqKnowledge 3.9. Data were pre-processed using a low pass filter and smoothed, and then evaluated using peak-to-peak analysis for each trial (each image/paired images presentation). The peak-to-peak amplitude was measured in micro-siemens ( $\mu\text{S}$ ) for the

first response that occurred between .5s-4.5s after stimulus onset (these methods were chosen based on previous SCR analysis recommendations, see: Figner & Murphy, 2011).

All measurements were then normalized using a square-root transformation.

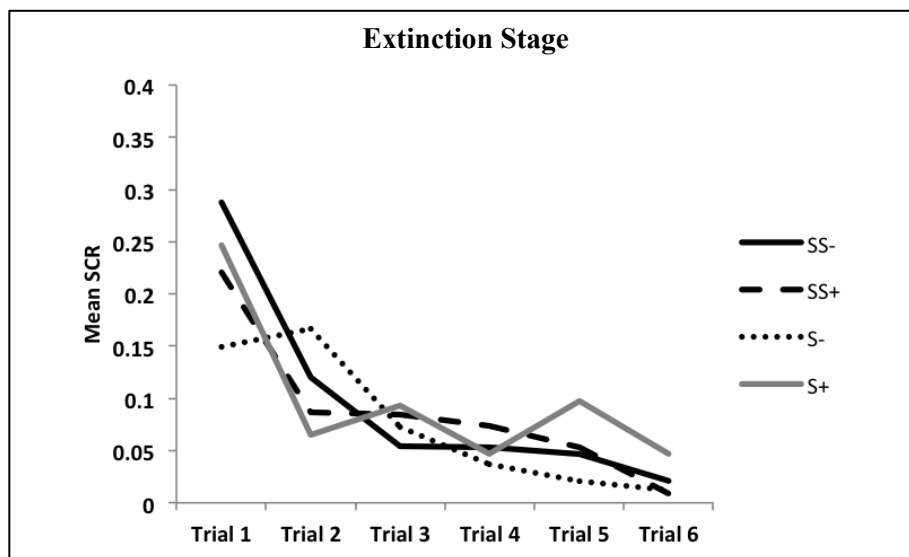
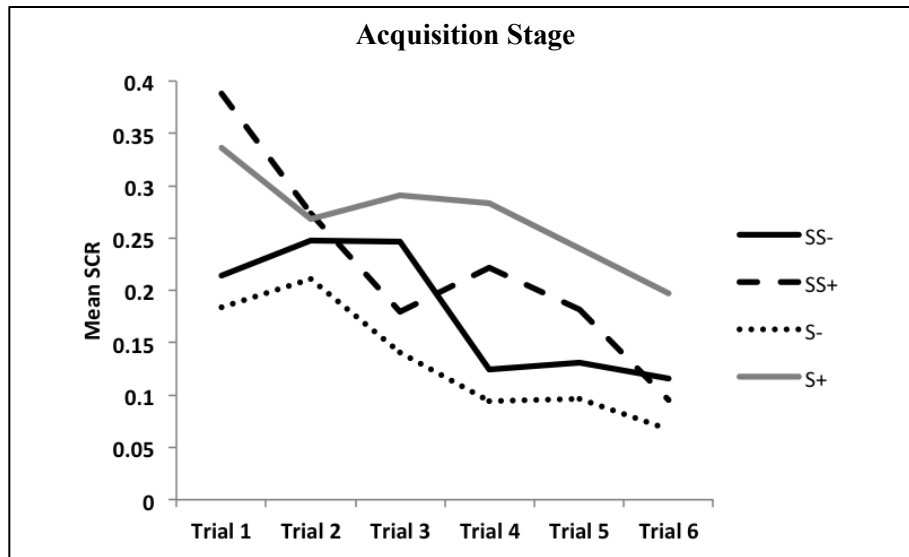
During any trial, if there was no peak (no rise in SCR) during the .5-4.5s stimulus window, the trial was scored as a zero response trial. In addition, a .02  $\mu$ S threshold was used for peak-to-peak amplitudes, thus if a peak-to-peak amplitude for any trial was below 02  $\mu$ S, the trial was scored as a zero response trial. Finally, if the participant moved during a trial, as recorded by the experimenter during the experiment session, the trial was excluded from data analysis.

**Scoring.** The habituation mean was calculated by averaging across all habituation trials. The acquisition mean was calculated by averaging across the final four trials of the acquisition stage for each stimulus. For each participant, if the acquisition mean was not greater for the CS+ than the CS- ( $CS+ - CS- > 0$ ) or if there were no peaks during any of the trials, it was considered that no conditional fear had been acquired for that condition. After acquisition, once the secondary image was removed and the original neutral images were presented alone once again, conditional fear response for each stimulus was compared using the first trial of the extinction stage for each stimulus type.

## **Additional Analyses and Data**

### *Trial-by-trial SCR*





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Paper 3:

Social support enhances extinction of learned fear responses

Erica Anne Hornstein & Naomi Ilana Eisenberger

## ABSTRACT

The ability to learn about cues that predict danger is critical for survival, however, this process can be inexact, resulting in disproportionate or disruptive fears. Treatment to extinguish these maladaptive fears has been shown to be only partially effective, with return of fear being a common and robust occurrence. This study examines whether the presence of social support stimuli leads to inhibited return of fear. We found that return of fear was inhibited for conditional fear stimuli paired with social support figures during fear extinction both following fear extinction and during a fear reinstatement test 24 hours later, but was not inhibited for strangers. Counter to what might be expected based on previous literature, these findings suggest that social support stimuli have unique safety signaling properties and may enhance fear extinction, revealing potential avenues of research exploring interventions to reduce and treat maladaptive fears.

The ability to learn about potential threats in the environment is crucial for survival. However, at times these learned fears can be maladaptive, producing excessive fears, disproportionate fear responses, or anxiety (Rosen & Schulkin, 1998; Craske & Waters, 2005). One common approach to treating maladaptive fears is exposure therapy, in which a fearful object or context is presented repeatedly in the absence of any danger, allowing for the integration of new, conflicting, information about the fearful cue (Craske, Kircanski, Zelikowsky, Mystkowski, Chowdhury, & Baker, 2008; Foa, Huppert, Cahill, Rothbaum, & Olasov, 2006; McNally, 2007). Exposure therapy is based on the fear extinction process. During this process, expectancies are violated when presentations of a conditional fear stimulus are made in the absence of an aversive event, leading to new learning that the conditional fear stimulus no longer predicts threat (Rescorla & Wagner, 1972; Bouton, 2004). Yet, fear extinction procedures in general, and exposure therapy in particular, are not always effective. Often the reduction of fear responding is only temporary, with the return of fear being a common and robust occurrence (Rachman, 1989; Craske, 1999; McNally, 2007). Therefore, developing a more detailed understanding of how to reduce or prevent the return of fear is extremely important.

The prevailing view in the clinical literature is that the presence of a learned safety signal during fear extinction diminishes the perception of threat, therefore reducing the fear response. However, this results in no reduction, or even an increase, in fear responding for a fearful cue once the safety signal is removed. During this process, known as protection from extinction, the presence of a learned safety signal (Lovibond, Davis, & O'Flaherty, 2000; Rescorla, 2003) or ability to engage in a learned safety behavior (avoidance behavior, see: Lovibond, Mitchell, Minard, Brady, & Menzies,

2009) when a fearful cue is presented during a fear extinction procedure inhibits fear extinction, such that the cue continues to elicit a fear response when presented alone. However, recent research indicates that certain safety stimuli can enhance fear extinction, suggesting that there might be cases in which this model does not fit. For instance, findings show that the presence of social support figure images enhances extinction of the learned fear response for other cues (Hornstein, Fanselow, & Eisenberger, in press). Moreover, the presence of social support figure images during fear extinction was also found to lead to continued inhibition of the fear response, such that even after social support images were removed, there was no fear response when the fearful cue was presented (Hornstein, et al., in press). This differs from what would be expected based on the protection from extinction literature reviewed above. In addition, findings show that the presence of a social support figure image can actually prevent the formation of fear associations (Hornstein & Eisenberger, in prep), indicating that these stimuli can impact the fear learning processes for other cues.

We have previously suggested that, unlike learned safety stimuli, social support figures may inhibit the return of fear because they act as prepared safety stimuli—stimuli that have historically enhanced survival and, without any specific safety training, are less readily associated with fear and inhibit fear responding. Indeed, social support increases our feelings of safety (Bowlby, 1969), mitigates psychological and neurocognitive appraisals of threat (Coan, 2008; Eisenberger, Master, Inagaki, Taylor, Shirinyan, et al., 2011), and diminishes our behavioral and physiological responses to danger (Epley, 1974; Thorsteinsson & James, 1999; Hennessy, Kaiser, & Sachser, 2009; Kiyokawa, Takeuchi, & Mori, 2007), indicating that it is a powerful safety signal. Hence, social

support figures may be a unique category of safety stimuli that has properties that diverge from those of typical safety stimuli. In order to further examine the effect of social support on fear extinction, we designed a study to investigate whether the presence of social support stimuli during fear extinction not only reduces fear responding in the same experiment session as previously shown, but also leads to a lasting reduction of the conditional fear response during later test sessions.

In order to test the impact of social support on fear extinction, we examined whether the presence of a picture of a social support figure (defined as the individual from whom the participant received the most social support on a daily basis) inhibited the return of the fear response during fear reinstatement tests conducted 24 hours and 2 weeks later. More specifically, we compared returned fear for conditional fear stimuli that were paired with either a social support figure's image or a stranger's image during fear extinction. While previous literature would suggest that a fear response would be present for both conditions at each fear reinstatement session, based on our previous findings (Hornstein, et al., in press) we hypothesized that while there would be a return of fear for conditional fear stimuli paired with strangers, none would return for conditional fear stimuli paired with social support figures.

## **Method**

### *Participants*

Data were analyzed from a final sample of 17 participants<sup>1</sup> (*mean age*=20.35, 13 *females*). A total of 39 participants were recruited, 1 was excluded based on the telephone

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<sup>1</sup> We are currently collecting data to reach our targeted sample size (n=20), and will update our results and discussion based on the analyses conducted with our final sample.

screening, 2 were excluded based on the SCR pre-screening, 1 did not return for the experiment session, 9 were excluded due to technical and procedural errors, 6 were excluded based on being low responders, and 3 were excluded based on not having acquired fear to both conditional fear stimuli during the fear acquisition stage (for more details regarding exclusion criteria, see supplemental materials). This sample size was based on previous research (see: Hornstein, et. al., in press, Olsson et al., 2005; Schiller et al., 2010). All participants were recruited at the University of California, Los Angeles (UCLA), and all experimental procedures were approved by the UCLA Institutional Review Board.

### *Procedures*

*Telephone Screening.* After a telephone screening with the experimenter, participants were excluded from participating if they were pregnant, had a history of mental illness, or were currently taking any mental health related medication.

*SCR Pre-Screening.* After passing the telephone screening, participants came into the lab for a 30-minute pre-screening session, during which it was determined if their Skin Conductance Response (SCR) could be detected by the equipment being used for the experiment (see supplemental materials). During the pre-screening session, participants were asked to identify “the individual who gives you the most support on a daily basis” and to rate how much social support they receive from that individual everyday on a scale of 1-10 (*mean*=8.77). Participants were instructed to send digital photographs of these individuals to the experimenter before returning for the experimental session.



*Experiment Session.* (Time-point 1) Upon returning to the lab for the experiment session, participants first underwent a shock calibration procedure in order to identify the level of shock to be applied during all three time-points of the experiment (see supplemental materials). For each participant, shock was calibrated to be extremely uncomfortable, but not painful. During all time-points of the experiment, SCR data, an index of physiological arousal, was collected as a measure of the learned fear response (see supplemental materials).

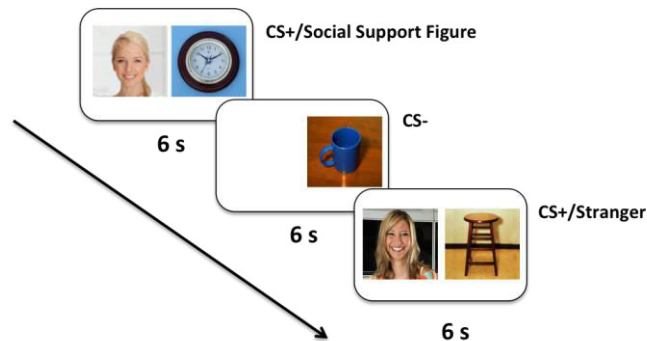
Participants then underwent a fear conditioning session with 4 stages: habituation, acquisition, summation, and test. During the session, 3 neutral stimuli (stool, cup, clock) were presented, two of which were paired with a secondary image during the summation stage. There were two secondary image conditions: 1) social support (social support figure image provided by the participant) and 2) stranger (an image of a stranger who was gender, age, and ethnicity matched to the social support figure). For each stage of the experiment, presentations were made in a pseudorandom order, and each image or combination of images was presented for 6s followed by a 10s ISI.

During the habituation stage, participants viewed three non-reinforced presentations of each neutral image. Comparison of each future CS+ to the CS- revealed no significant difference in mean SCR, for CS+s later to be paired with images of strangers,  $t(16)=-.204$ ,  $p=.841$ , 95% CI[-0.07,0.05], or CS+s later to be paired with social support figures,  $t(16)=-1.63$ ,  $p=.123$ , 95% CI[-0.09,0.01] indicating that there were no pre-existing characteristics that could account for later differences in SCR.

In the acquisition stage, participants viewed 4 reinforced presentations of two neutral images that were consistently presented (100% reinforcement schedule) with a co-terminating 200ms electric shock (CS+'s), and 8 non-reinforced presentations of the third neutral image (CS-).

Participants then had a short break, during which they watched the first 3 minutes of a video clip about airplanes.

Following this, there was the summation stage, during which participants viewed 4 non-



**Figure 1.** Example of trials during the summation stage of the experiment. After acquiring a conditional fear response for two CS+s during an acquisition stage, each CS+ was paired with one image type (social support figure, or stranger) and a CS- was presented alone.

reinforced presentations of each CS+ consistently paired with one secondary image (social support or stranger), and 4 non-reinforced presentations of the CS- presented alone (see Fig. 1). The CS+/secondary image pairings were counterbalanced across participants such that each CS+ type was paired equally with each secondary image type. After the summation stage was complete, participants watched the final 3 minutes of the video clip.

Finally, in the test stage, participants viewed 4 non-reinforced presentations of each original CS+ alone, with the secondary image removed, and of the CS-.

*Follow-up 1.* (Time-point 2) Participants returned to the lab 24 hours following the completion of the experiment session and underwent a fear reinstatement procedure (Rescorla & Heth, 1975). During this procedure, three unsignaled 200ms electric shocks

were applied followed by a 30s break after which 3 non-reinforced presentations of each CS+ and the CS- were presented.

*Follow-up 2.* (Time-point 3) Participants returned to the lab 2 weeks following the completion of the experiment session and completed the same fear reinstatement procedure conducted during follow-up 1.

#### *Data Analysis Strategy*

Before analyzing the data, we determined whether each participant had acquired fear to both CS+s by evaluating whether the acquisition mean for each CS+ was greater than that of the CS- ( $CS+ - CS- > 0$ ). In order to ensure that each CS+ elicited a fear response that could be inhibited during the summation stage and reinstated during the follow-up sessions, if fear was not acquired for both CS+s, the participant's data was excluded from the experiment.

For the acquisition stage, paired-samples t-tests were conducted comparing the acquisition means in order to determine if a fear response was acquired for each CS+, indicated by significantly higher SCR elicited for a CS+ compared to that of the CS- (see supplemental materials for details).

For the summation stage, paired-samples t-tests were conducted comparing the summation means in order to determine if the fear response for each CS+ was inhibited, indicated by no significant difference in SCR elicited by a CS+/secondary image pairing compared to that of the CS-. If this difference was significant, it was considered to indicate a fear response was exhibited, and that no inhibition occurred.

For the test stage, paired-samples t-tests were conducted comparing the test means in order to determine if a fear response was present for each CS+ when it was once again

presented alone (with the secondary image removed), indicated by significantly higher SCR elicited by a CS+ compared to that of the CS-. Additionally, paired-samples t-tests were run comparing extinction means (drawn from the final two trials of the test stage) for each CS+ compared to the CS- in order to ensure that extinction occurred, indicated by no significant differences in mean SCR, allowing us to examine fear reinstatement during each follow-up session.

Finally, for each follow-up stage, paired-samples t-tests were run comparing the follow-up means in order to determine if fear was reinstated for each CS+, again indicated by significantly higher SCR elicited by a CS+ compared to that of the CS-.

We also compared the mean difference scores (CS+ - CS-) for each secondary image condition (social support, stranger) in order to examine the effect of condition on: 1) fear inhibition, using means from the summation stage, 2) return of fear, using means from the test stage, 3) fear reinstatement, using means from each follow-up stage, and 4) increase in fear across stages in the social support condition.

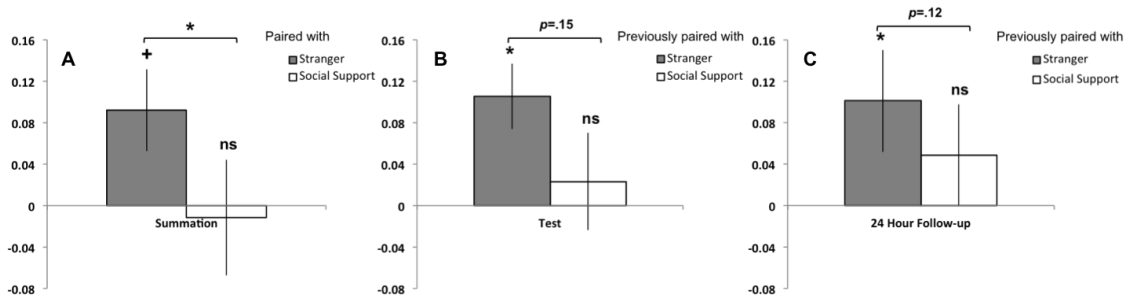
## **Results**

We first examined whether fear was acquired for both CS+s during the acquisition stages, allowing us to examine fear inhibition, return, and reinstatement in the later stages. We found a significant conditional fear response for CS+s that would later be paired with stranger secondary images,  $t(16)=6.45$ ,  $p<.001$ , 95% CI[0.13,0.26], and with social support secondary images,  $t(16)=7.05$ ,  $p<.001$ , 95% CI[0.15,0.29], indicating fear was acquired for both CS+s. Additionally, there was no significant difference in SCR for the two CS+s ( $p>.5$ ), indicating fear acquisition was equivalent for both conditions.

We then examined whether fear was inhibited during the summation stage by evaluating fear responses for the CS+/secondary image pairings. Replicating our previous findings (Hornstein et al., in press), results showed that no fear inhibition occurred when a CS+ was paired with a stranger secondary image, indicated by a marginally higher SCR response to the CS+/stranger image pairing compared to the CS-,  $t(16)=1.89$ ,  $p=.077$ , 95% CI[-0.01,0.20], but fear inhibition did occur when a CS+ was paired with a social support secondary image, indicated by no significant difference in SCR for the CS+/social support image pairing compared to the CS-,  $t(16)=-.264$ ,  $p=.795$ , 95% CI[-0.10,0.08], (see Fig. 2a). Further comparison across these responses showed a significant difference,  $t(16)=2.08$ ,  $p=.05$ , 95% CI[-0.001,0.21], such that there was a significantly lower fear response elicited by CS+s paired with social support figure images compared to those paired with stranger images.

Additionally, we examined whether a conditional fear response was present after the secondary image was removed, by examining responses to each CS+ compared to the CS- during the test stage. Again, replicating our prior findings (Hornstein et al., in press), we found that a conditional fear response was present for CS+s that had been paired with a stranger's image during the summation stage,  $t(16)=2.23$ ,  $p<.05$ , 95% CI[0.005,0.19], but there was no conditional fear response present for the CS+s that had been paired with a social support figure's image,  $t(16)=1.07$ ,  $p=.301$ , 95% CI[-0.03,0.09], (see Fig. 2b). When comparing across these responses, there was only a trend towards significance ( $p=.15$ ), but it possible that with the addition of the last three participants, this comparison will become significant.

In order to ensure that all conditional fear responses were extinguished prior to the follow-up sessions, thus allowing us to evaluate fear reinstatement, we evaluated whether CS+s from either condition resisted fear extinction. We assessed fear extinction



**Figure 1.** Results from the summation, test and 24 hour follow-up stages of the experiment. At all stages, the presence of a conditional fear response was assessed by comparing mean SCR for each CS+/secondary image pairing (summation) or each CS+ (test and follow-up) to the CS-. All error bars indicate standard error. Asterisks indicate a significant difference score ( $p < .05$ ), “+” indicates a marginal difference score ( $p < .1$ ), and “ns” indicates no significant difference. A). Summation stage: presentation of each CS+ was paired with one secondary image type (social support figure or stranger) and the CS- was presented alone. Results show that fear was inhibited in the social support condition, but not in the stranger condition. B). Test stage: presentations of each CS+ and the CS- after the secondary images had been removed. Results show return of fear for the stranger condition, but not for the social support condition. C). 24 hour follow-up: 24 hours after the completion of fear extinction, participants returned to the lab for a fear reinstatement test during which they saw presentations of each CS+ alone and the CS-. Results show fear reinstatement for the CS+ that had been previously paired with a stranger’s image, but not for the CS+ that had previously been paired with a social support figure’s image.

by comparing responses for each CS+ to those for the CS- during the second half of the test stage (during which non-reinforced presentations of all stimuli were presented).

These comparisons showed that the conditional fear response was extinguished for CS+s paired with both stranger images,  $t(16)=1.08$ ,  $p=.295$ , 95% CI[-0.02,0.07] and social support figure images,  $t(16)=-.853$ ,  $p=.406$ , 95% CI[-0.03,0.10], and there was no difference across conditions ( $p=.57$ ). These results show that there was no fear response present in either condition at the end of the test stage, indicating that fear extinction occurred in both conditions and that fear responding measured in later sessions would be due to fear reinstatement.

For each follow-up session, we evaluated whether a fear response was reinstated for CS+s in each condition. During follow-up session 1, which took place 24 hours following the completion of the experimental session, we found that fear was reinstated for CS+s that had been paired with stranger images,  $t(16)=2.63$ ,  $p=.018$ , 95% CI[0.02,0.23], but there was no reinstatement of the conditional fear response for CS+s paired with social support figure images,  $t(16)=1.36$ ,  $p=.193$ , 95% CI[-0.03,0.16], (see Fig. 2c). Comparing across these responses, however, revealed a trend towards significance ( $p=.12$ ), although it is possible that this comparison will become significant when we run the final three participants. For follow-up session 2, which took place two weeks following the completion of the experimental session, we found that there was no reinstatement of fear in either the stranger or social support condition ( $p's>.9$ ). The fact that fear was not reinstated in even the stranger condition suggests that our fear conditioning procedures were not a powerful enough test our hypothesis—they did not generate conditional fears that could be reinstated two weeks later. Further examination of fear reinstatement at this time-point is therefore required.

Additional examination of fear responses in the social support-paired condition across stages across stages revealed no significant differences ( $p's>.46$ ). Therefore, although SCR for the social support-paired condition increases as the stages continue (summation to test, test to follow-up 1), this increase is not significant.

## **Discussion**

In order to safely and efficiently navigate the world, the ability to identify cues that predict danger and threat is critical. However, the process by which this knowledge is

acquired is often imprecise, resulting in the formation of fears that are inaccurate, disproportionate, and disruptive. These maladaptive fears can be extremely harmful, leading to anxiety or excessive fear responses and increasing psychological and physiological stress. Exposure therapy, based on fear extinction processes, is often used to treat these fears, but this intervention has been found to be only partially effective, and fear tends to return over time. Hence, the current research seeks to develop understanding of possible methods for decreasing return of fear by exploring the impact of social support stimuli on the fear extinction process.

While previous literature would suggest that the presence of a safety signal during fear extinction processes should lead to a return of fear, recent research has demonstrated that the presence of certain safety signals, specifically social support stimuli, during fear extinction inhibits return of fear (Hornstein, et al. in press). Building on these novel findings, we examined whether the presence of social support stimuli during a fear extinction process not only led to enhanced fear extinction within the experimental session, but also reduced return of fear at later time points. Results showed that pairing a social support stimulus with a fearful stimulus during fear extinction led to decreased return of fear. While results from a time-point 2 weeks following the completion of fear extinction showed no return of fear for either condition, (most likely due to the strength of our fear conditioning manipulation, and thus not interpretable), results from a time-point 24 hours following the completion of fear extinction show that social support inhibits the return of fear. Specifically, during a fear reinstatement test, there was return of fear for fearful cues that had been paired with images of strangers, but there was no return of fear for those that had been paired with images of social support figures.



These surprising findings suggest that there are special properties of social support stimuli distinct from those of typical safety stimuli. Research concerning protection from extinction has examined the impact of learned safety signals (Lovibond, et al., 2000; Rescorla, 2003) or avoidance behavior (Lovibond, et al., 2009) on fear extinction. It is thought that in both cases, protection against extinction occurs because the expectation of an aversive outcome is reduced by the presence of the safety signal, leading to no violated expectations during fear extinction and consequently no change in associative strength for the fearful stimulus (Rescorla & Wagner, 1972; Hermans, Craske, Mineka, & Lovibond, 2006). However, these safety signals and behaviors are not imbued with the rich history of care, security, and resources that have been provided by social support figures, and these characteristics may explain the unique safety signaling functions of social support. It is possible that instead of reducing the expectation of an aversive outcome, social support stimuli increase perceptions of access to care and resources, fostering assessment of coping abilities and diminishing the perceived aversiveness of an event. Indeed, social support has been demonstrated to decrease perceptions of pain (Brown, Sheffield, Leary, and Robinson, 2003; Master, et al., 2009; Younger, Aron, Parke, Chatterjee, & Mackey, 2010) and to decrease neural activity in regions associated with the distressing aspect of pain (Eisenberger, et al., 2011), suggesting that social support mitigates the psychological discomfort and distress evoked by painful experiences.

In addition, social support may work on a neurochemical level to alter the physiological experience of painful or aversive events. It has been suggested that the opioid system, a primitive pain mechanism, is among the neural substrates that support

modern separation distress, and opioids have been shown to attenuate separation distress and to be released during social contact (for a review, see: Nelson & Panskepp, 1998). Given the important role opioids are known to play in fear acquisition (Fanselow, 1981) and fear extinction (McNally & Westbrook, 2003), and in creating negative feedback during the fear learning process (consistent with the Rescorla-Wagner model of conditioning, see: Fanselow, 1981; Fanselow, 1998), it is possible that social support disrupts fear learning and fear extinction via the opioid system. More specifically, social support may trigger the release of endogenous opioids, providing unsignaled analgesia, buffering against the pain of an aversive event and interfering with the negative feedback model that supports fear learning and fear extinction.

These underlying mechanisms may explain the distinct safety signaling properties provided by social support. In prior work, we have demonstrated that social support figures are one category of prepared safety stimuli, suggesting that they are powerful fear inhibitors that naturally signal safety, less readily becoming associated with threat and inhibiting the conditional fear response. As prepared safety stimuli, social support figures have also been shown to perform unexpected functions: preventing the formation of fear associations with other cues, decreasing return of fear after a fear extinction process, and, in the present work, reducing the return of fear during a fear reinstatement test 24 hours after fear extinction is complete (Hornstein, et al., in press; Hornstein & Eisenberger, in prep). Altogether, these findings suggest that social support figures, as prepared safety stimuli, play a unique safety signaling role that may be supported by different underlying processes than those performed by typical safety signals.

In order to investigate the mechanisms underlying social support's unique safety effects, more work must be conducted. For example, examination of participants' expectation and experience of threat during fear extinction will shed light on whether social support alters perceived ability to cope with shock or other aversive events. Additionally, examination of the role the opioid system plays in the social support effect will clarify whether social support interferes with the negative feedback model, consequently enhancing fear extinction.

Future work must also explore the boundaries of these social support safety effects. Examining whether social support enhances extinction for stimuli that are fear-relevant, such as snakes and spiders, for which fear associations are more analogous to those held for extreme fears, may more closely match the impact of social support on fear extinction for excessive fears or anxiety. Moreover, the use of fear relevant stimuli may strengthen fear conditioning manipulations, and fear associations, thus allowing for examination of the social support effect at time-points beyond 24 hours. In addition, extending this work to include clinical populations will reveal a clearer picture of how social support might be integrated into research regarding the treatment of maladaptive fears.

Overall, the results presented here build on previous research demonstrating the unique safety signaling properties of social support, showing that social support stimuli enhance fear extinction and decrease the return of fear. While further research is required, these findings provide insight into the mechanisms underlying social support's distinct safety characteristics and reveal potential avenues of research for treatment strategies targeted at reducing excessive fears and anxiety.

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## SUPPLEMENTAL MATERIALS

### **Materials and Methods**

#### *Screening and Procedures*

**SCR pre-screening session.** In order to determine if the equipment to be used for the experiment could detect a participant's response, and SCR screening test was conducted. SCR for all participants was measured using the BioPac MP100 system with EDA Isotonic Gel Electrodes, and data were collected using AcqKnowledge 3.9 software (BioPac Systems, Inc., Aero Camino Goleta, CA). For the SCR pre-screening session, the following experiment session, and both follow-up sessions, electrodes were placed on the palmar side of participants' medial phalanges on the fore and middle fingers of the left hand. During the test, participants were asked to breath in deeply in order to activate the sympathetic nervous system and consequent increases in SCR. The experimenter monitored their responses and determined if an SCR increase was detected. If the equipment did not detect a participant's response, he or she was excluded from the experiment.

**Experiment Session.** Each participant underwent an electric shock calibration procedure was conducted at the beginning of the experiment session in order to determine the appropriate level of shock to be applied during the experiment. Electric shock was applied to participants via a bar lead electrode placed on the write wrist, and was delivered from a SD9 Pulse Stimulator from Grass Technologies (Natus Neurology, Inc. – Grass Products, Middleton, WI). During the calibration procedure participants were exposed to a 200ms electric shock starting at 30 volts, and increasing in 5-volt increments. Participants were instructed to inform the experimenter when the shock

became extremely uncomfortable, but not painful, and it was at that level that participants were shocked during the experiment session. This work-up procedure was used in previous research (see: Hornstein, Fanselow, & Eisenberger, in press, Hornstein & Eisenberger, in prep) and was informed by work-up procedures from prior studies in which shock was used during human fear conditioning (see: Olsson, Ebert, Banaji, & Phelps, 2005; Phelps, Delgado, Nearing, & LeDoux, 2004; Schiller, Monfils, Raio, Johnson, LeDoux, & Phelps, 2010). For this experiment, average voltage (as decided upon by the experimenter and the participant during the shock calibration procedure) was 47.35 volts.

All stimuli were presented using E-Prime 2.0 software (Psychology Software Tools, Inc., Sharpsburg, PA).

### *Data Analysis*

**Participants.** The target sample size for this experiment is  $n=20$ , and participants are currently being recruited in order to reach this target. Target sample size as well as the exclusion criteria, described above, were chosen based on those used in previous human fear conditioning studies (see: Hornstein, et al., in press; Hornstein, et al., in prep; Olsson, et. al., 2005; Schiller, et. al., 2010).

**Pre-processing.** SCR data were collected and pre-processed using AcqKnowledge 3.9 software. All data were pre-processed using a low-pass filter and smoothed, and were evaluated using peak-to-peak analysis for each trial (meaning each stimulus/paired stimulus presentation). For each trial, responses were measured as the first peak that occurred between .5s-4.5s after stimulus onset, and peak-to-peak amplitude



was measured in micro-siemens ( $\mu\text{S}$ ) (these procedures were selected based on previous SCR analysis recommendations, see: Figner & Murphy, 2011). All measurements were normalized using a square-root transformation.

Trials were scored as zero response trials or excluded from analysis under certain conditions. If there was no peak (no rise in SCR) during the .5-4.5s stimulus window, the trial was scored as a zero response trial. In addition, a .02  $\mu\text{S}$  threshold was used for peak-to-peak amplitudes, thus if a peak-to-peak amplitude for any trial was below 02  $\mu\text{S}$ , the trial was scored as a zero response trial. Finally, if the participant moved during a trial, as recorded by the experimenter during the experiment session, the trial was excluded from data analysis.

If participants displayed SCR on fewer than 25% of the trials during acquisition, they were considered to be low responders and were thus excluded from analysis, resulting in 6 participants being excluded from analysis.

**Scoring.** The habituation mean was calculated by averaging across all habituation trials.

The acquisition mean was calculated by averaging across the last 3 trials of acquisition for each CS+ and the last 6 trials of acquisition for the CS- (the final 75% of the stimulus presentations for each type). In order to determine if learning had occurred for both CS+s prior to the summation, test, and follow-up stages, the acquisition mean for each CS+ was compared to that of the CS-. If the acquisition mean for a CS+ was not greater than that of the CS- for each participant ( $\text{CS+} - \text{CS-} > 0$ ), or if there were no peaks during the trials comprising the acquisition mean, participants were considered not to

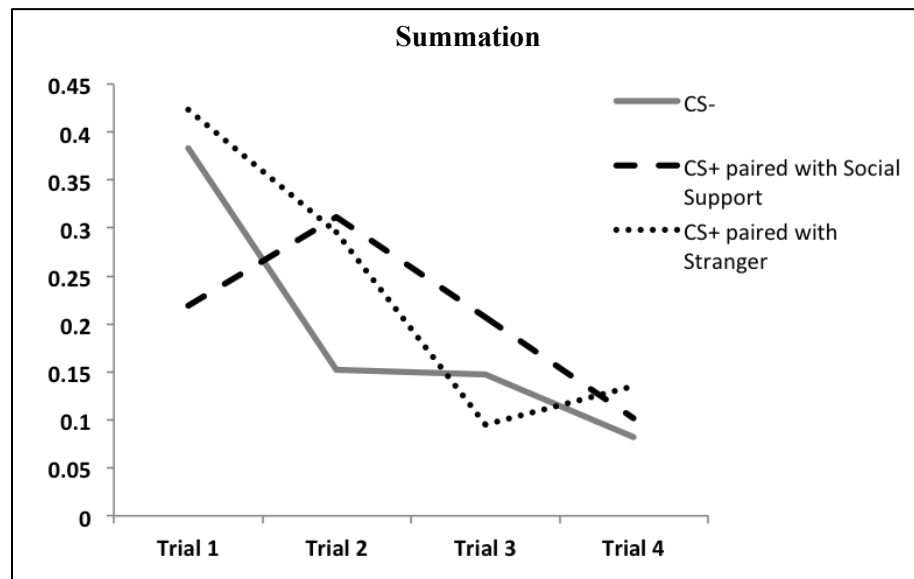
have acquired fear for that CS+ and were excluded from analysis. A total of 3 participants were excluded because they did not acquire fear for both CS+s.

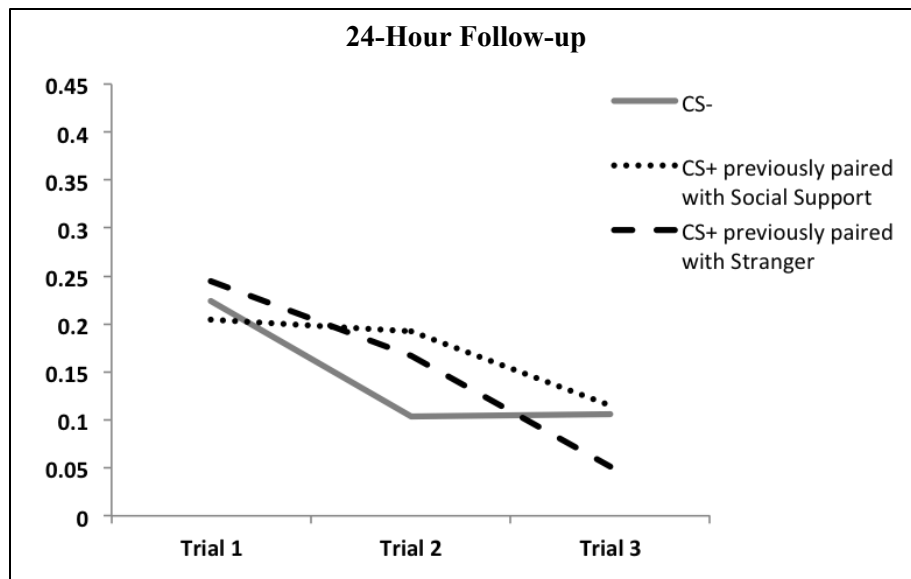
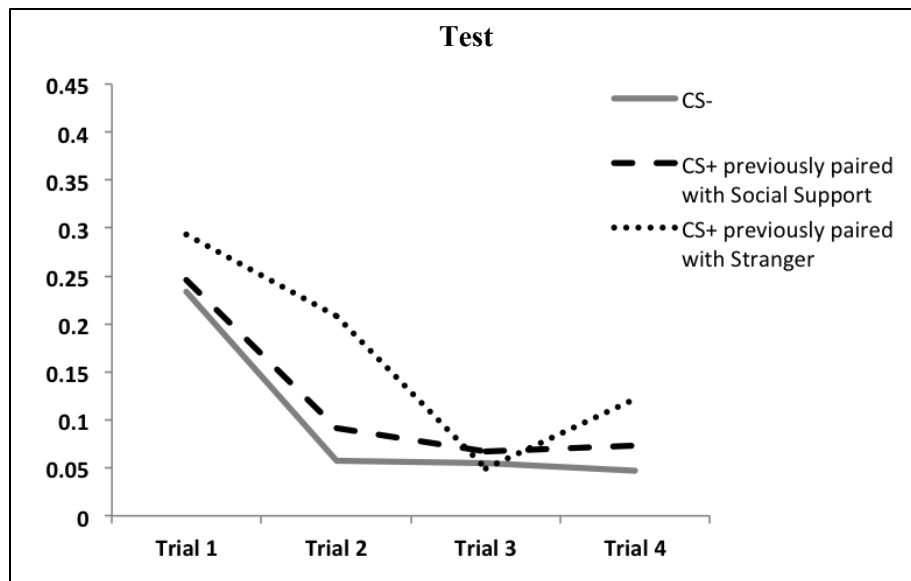
The summation mean was calculated by averaging across the first two trials of summation for each stimulus. Similarly, the test mean was calculated by averaging across the first two trials of test. These measurements were based on previous research, and were chosen in order to assess summation and test without including later trials during which extinction might have occurred (see: Hornstein, et al., in press).

For each follow-up session, fear responding was assessed using SCR from first presentation of each stimulus type, chosen in order to avoid including trials during which fear extinction might have occurred and new CS+/US contingencies have formed.

## Additional Data and Analyses

### *Trial-by-trial SCR*





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## CONCLUSION

Our close relationships provide us with safety, security, and protection, and thus may have come to be powerful safety signals that have the potential to reduce fear. The three papers in this dissertation bridge the social support and Pavlovian conditioning literatures for the first time, introducing prepared safety stimuli, testing whether social support is one category of prepared safety, and investigating its impact on fear learning processes. Altogether, this work helps to provide a richer understanding of the ways in which social support might reduce learned fears, and offers insight into how social support might be integrated into interventions to improve mental and physical health outcomes. Below, I give a summary of the contribution of each paper and review the implications of this research as a whole.

Paper 1 sought to answer the question of whether social support stimuli are one category of prepared safety stimuli. Drawing on theory and methods from the literature on social support and Pavlovian conditioning, Paper 1 achieved three goals. First, building on the concept of conditioned inhibitors (Rescorla, 1969), a definition of prepared safety stimuli was developed as follows: prepared safety stimuli should perform the functions of a conditioned inhibitor without requiring any specific safety training. Second, social support was shown to pass the tests of a conditioned inhibitor, both less readily becoming associated with fear (study 1) and inhibiting the conditional fear response (study 2), indicating that social support is one category of prepared safety. Third, the prepared safety properties of social support stimuli were demonstrated to derive from perceptions of support provided, not other positive characteristics of these stimuli. Specifically, it was shown that while fear could not be associated with social

support stimuli, fear was associated with stimuli that were familiar or rewarding, suggesting that the familiar or rewarding properties of social support stimuli do not account for their prepared safety effects. Collectively, these results begin to shape our understanding of prepared safety stimuli in general, and the functions of social support in particular, opening the door for further investigation.

In Paper 1, social support stimuli were shown to be one category of prepared safety. In Papers 2 and 3, this finding was built upon by examining the impact of social support on the fear learning process. Thus, in Paper 2, the effect of social support on fear acquisition was examined. Results reveal that the presence of social support stimuli during fear acquisition prevented the formation of fear associations with other cues. This finding dovetails nicely with previous research demonstrating the link between social support and positive mental and physical health outcomes (House, et al., 1998, Cohen & Wills, 1985, Cacioppo, et al., 2006), suggesting that one mechanism through which social support benefits health is by reducing learned fear associations and, consequently, psychological and physiological responses to perceived threats.

Paper 3 further builds understanding of the impact of social support on fear learning processes by investigating the effect of social support on fear extinction. Based on previous findings demonstrating that social support stimuli lead to continued fear inhibition after fear extinction (*Paper 1*: Hornstein, et al., in press), it was predicted that the presence of social support stimuli during fear extinction would inhibit the return of fear. Results demonstrated that social support inhibited return of fear directly following and at 24-hours post fear extinction, suggesting that social support enhances the fear extinction process. While these findings are counter to previous literature, which

indicates that the presence of a learned safety signal during fear extinction increases the return of fear (Lovibond, et al., 2000; Lovibond, et al., 2009; Rescorla, 2003), they reveal a clearer picture of the safety signaling properties of social support as a prepared safety stimulus, and suggest that these properties might diverge from those held by learned safety signals.

Altogether, the findings from this dissertation contribute to scientific understanding of the unique safety signaling properties of prepared safety in general, and social support in particular. However, much more work is left to be done. It is my hope that the phenomenon illuminated here will form the foundation for future research targeted at uncovering the mechanism by which social support provides these unique safety effects and discovering how social support might be integrated into interventions targeted at improving mental and physical health.

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