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## Attachment, skin deep? Relationships between adult attachment and skin barrier recovery

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### Abstract

This study examined the relationship between individual differences in adult attachment and skin barrier recovery. Dating couples ( $N = 34$ ) completed a self-report measure of attachment anxiety and avoidance, and during two separate laboratory visits, normal skin barrier function was disrupted using a tape-stripping procedure, followed by a 20 min discussion of personal concerns in one visit and relationship problems in the other, counterbalanced randomly across visits. Skin barrier recovery was assessed by measuring transepidermal water loss up to 2 h after skin disruption. Multilevel modeling showed that skin barrier recovery did not differ between the personal concern or relationship problem discussions. Among women, greater attachment anxiety predicted faster skin barrier recovery across the two visits, while greater attachment avoidance predicted slower skin barrier recovery. Among men, greater attachment anxiety predicted slower skin barrier recovery during the personal concern discussion only. The observed effects remained significant after controlling for transepidermal water loss in undisturbed skin, suggesting that the relationship between attachment security and skin barrier recovery was not due to other skin-related factors like sweating. Cortisol changes, self-reported emotions, stress appraisals, and supportiveness ratings were tested as potential mediators, and none explained the relationships between attachment and skin barrier recovery. These findings are the first to demonstrate associations between individual differences in attachment style and restorative biological processes in the skin, even in a sample of young dating couples in satisfied relationships.

### Keywords

attachment; wound healing; close relationships; couple interactions; skin barrier recovery

## 1. Introduction

Relationships are central to human life, and the quality of one's social connections has a strong influence on health (Uchino, 2004). Within our intimate relationships, conflict is often related to physiological changes characteristic of the fight-or-flight response (Robles and Kiecolt-Glaser, 2003), which can be dampened by supportive behaviors (Robles et al., 2006). The physiological changes associated with support and strain in relationships are

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frequently cited as key mechanisms explaining how the quality of close relationships can “get under the skin” and impact physical health (Loving et al., 2006; Robles and Kiecolt-Glaser, 2003; Slatcher, 2010). However, much like research on physiological responses to acute stress (Kiecolt-Glaser et al., 1992), many of the observed changes in cardiovascular, endocrine, and immune function in response to interpersonal interactions are well within the normal ranges, and their clinical significance is unclear. Thus, determining whether the physiological changes associated with close relationship events have meaningful consequences for health is a key direction for the field (Pietromonaco et al., in press).

The skin is an ideal organ system in which to study the interplay between close relationship functioning and health. The primary function of skin is to provide a protective barrier for internal tissues against the outside world through physical, chemical, and biological means (Elias, 2005). The skin is highly innervated by the central nervous system and is a target for neuroendocrine factors involved in the stress response (Arck et al., 2006). In addition, chemical messengers in the immune system (cytokines), play significant roles in the barrier function of the skin, particularly restoration of the barrier following damage through physical injury (Nickoloff and Naidu, 1994). Even minor damage to the skin, such as the removal of cells in the upper layer of the epidermis through a carpet burn, initiates a cascade of immune-mediated events involved in repairing the skin barrier, and these events occur immediately following damage to the skin. For example, immediately after skin barrier disruption, pre-formed proinflammatory cytokines are released in the upper epidermal layer (Hauser et al., 1986; Tsai et al., 1994; Wood et al., 1997), and proinflammatory cytokines are synthesized in the hours following disruption (Nickoloff and Naidu, 1994). Studying the effects of psychosocial factors on skin repair provides a clinically relevant health outcome that can be measured in a short amount of time in healthy individuals.

Importantly, skin function is influenced by psychological stress. According to a recent meta-analysis, stressors including laboratory tasks, academic exams, and chronic stress are related to delayed skin barrier recovery, with a moderate effect size ( $r = -.38$ ) (Walburn et al., 2009). For example, performing an acute laboratory stressor was related to delayed skin barrier recovery 2 – 3 hours later (Altemus et al., 2001; Robles, 2007). Social support provided by a confederate before the stressor did not influence recovery (Robles, 2007), leading us to conclude that support from an individual's social network, such as the presence of a significant other, may have greater bearing on skin barrier recovery and wound healing.

Indeed, social bonds are related to wound healing in both animals and humans. Socially isolated rodents show slower wound healing following exposure to an immobilization stressor compared to socially housed rodents (Detillion et al., 2004). Moreover, in two monogamous mouse species, separation from partners prior to wounding was related to delayed wound healing (Glasper and DeVries, 2005). In addition, paired mice that were physically separated by a mesh barrier but still able to see and smell each other showed faster wound healing compared to isolated mice. In humans, greater perceived stress was related to delayed skin barrier recovery in a sample of women, of whom half were going through divorce or separation (Muizzuddin et al., 2003). Beyond the presence or absence of close others, the quality of close relationships is also related to wound healing. Specifically, blister wound healing was slower during a hospital visit that included a problem-solving discussion designed to elicit conflict, compared to a personal concern-related discussion designed to elicit support, and couples who showed more negative behaviors during those discussions had slower wound healing (Kiecolt-Glaser et al., 2005). Taken together, these findings suggest that close relationships may be an important factor in skin barrier recovery and wound healing.

Thus far, research on the links between close relationships and skin function, and close relationships and physical health outcomes more broadly, has focused primarily on presence (in animals) or quality of social relationships (in humans). In humans, relationship quality is measured by observing behavior during interpersonal discussions or asking individuals to report their perceptions of social support, social strain, or relationship satisfaction. However, perceptions of relationship quality and behavior in interpersonal interactions are shaped in part by the individual and relational histories that individuals bring to the relationship. Adult attachment theory provides a framework for characterizing and measuring contributions of such individual differences to close relationships (Fraley and Shaver, 2000).

According to adult attachment theory (Bowlby, 1969; Fraley and Shaver, 2000), individuals have an innate behavioral attachment system that monitors the presence and responsiveness of attachment figures, including caregivers in infancy and romantic partners in adulthood. Moreover, early-life experiences with caregivers lead to variations in the attachment system along two independent dimensions: 1) attachment *anxiety*, and 2) attachment *avoidance* (referred to here as anxiety and avoidance). The anxiety dimension captures the degree to which individuals worry about rejection or loss of closeness in a romantic relationship. The avoidance dimension captures the degree to which individuals are uncomfortable with intimacy and closeness in a romantic relationship. These dimensions were originally thought to reflect features of social-cognitive models of the self and the close relationship partner, referred to as *internal working models*, but more recent conceptualizations view the dimensions as reflecting the organization of attachment behavioral system dynamics more generally (Fraley & Shaver, 2000). According to Fraley and Shaver (2000), the anxiety dimension is primarily an appraisal-monitoring system that gauges the closeness of the attachment figure and monitors for threat-related cues, while the avoidance dimension regulates behavior towards or away from the attachment figure, especially during anxiety-provoking situations. The systems are thought to operate in parallel, to influence each other via reciprocal feedback, and to operate automatically. Importantly, individuals differ in the degree to which they monitor closeness and maintain distance; some overly monitor their relationship for signs of threat and others overly distance themselves from close others.

Given the importance of close social relationships more generally (Uchino, 2004), and the role of the attachment system in monitoring and regulating distance in those relationships, and emotion regulation more broadly, many propose that the attachment system plays an important role in physical health (Diamond and Fagundes, 2010; Hofer, 1984; Maunder and Hunter, 2001; Pietromonaco et al., in press; Sbarra and Hazan, 2008). One reason for hypothesizing a role in physical health is research showing relationships between adult attachment and stress-responsive biological systems, including the hypothalamic-pituitary-adrenal (HPA) axis (Brooks et al., 2011; Diamond and Fagundes, 2010; Kidd et al., 2011; Powers et al., 2006), autonomic nervous system (Diamond et al., 2006; Holland and Roisman, 2010; Maunder et al., 2006; Roisman, 2007a), and more recently, the immune system (Gouin et al., 2009).

Specifically, greater *insecure attachment*, including high anxiety or high avoidance, are related to elevated reactivity to brief laboratory stressors, including public speaking and mental arithmetic, in the HPA axis and the sympathetic branch of the autonomic nervous system (Diamond and Fagundes, 2010). In addition, greater attachment avoidance in women and anxiety in men predicted greater cortisol reactivity to a problem-solving discussion (Powers et al., 2006). In our recent work from the same sample as this study, greater attachment anxiety in men predicted greater cortisol reactivity to a problem-solving discussion, and greater attachment avoidance in men predicted greater partners' cortisol reactivity to a problem-solving and personal concern discussion (Brooks et al., 2011). Taken together, these studies demonstrate the role of the attachment system in stress-responsive

biological systems, and suggest that there may be gender differences in the relationship between adult attachment and physiological responses to interpersonal discussions.

Activity in stress-responsive biological systems are also proposed as explanatory mechanisms for links between psychosocial factors and skin function (Garg et al., 2001; Robles and Carroll, 2011). Animal models suggest that enhanced levels of cortisol impair wound healing. For example, wound healing delays in stressed hamsters were reversed by suppression of cortisol production (Detillion et al., 2004), and the effects of stress on skin barrier recovery can be blocked by glucocorticoid antagonists (Choi et al., 2006). In addition, the skin is highly innervated by sympathetic nerves, which cause sweating, and may also contribute to wound healing (Souza et al., 2005). Thus, taken together with evidence suggesting that social context can modulate wound healing, the attachment system may have implications for skin barrier recovery and wound healing.

The aims of the current study were to examine the association between attachment and skin barrier recovery in the context of couple interactions, and in a sample of young, healthy dating couples in committed relationships. While studies involving couple interactions and physiology in the laboratory typically focus on discussions involving problems in the relationship, couples frequently turn to each other for support when discussing personal concerns (Gable et al., 2006; Pasch and Bradbury, 1998). Thus, in this study couples participated in two visits similar to prior work (Kiecolt-Glaser et al., 2005). During one visit, couples discussed an area of personal concern, intended to promote the exchange of social support. During the other visit, couples attempted to solve problems in their relationship. Prior to the discussions, the skin barrier was disrupted in both partners using tape-stripping, and we also collected salivary cortisol and psychological responses during the visits.

Based on the prior research in married couples and blister wound healing described above, we expected slower skin barrier recovery during the problem discussion visit compared to the personal concern visit. In addition, we expected greater insecure attachment (operationalized here as high attachment anxiety or high attachment avoidance) to predict slower skin barrier recovery across visits. We also tested potential physiological (cortisol) and psychological (self-reports of mood, supportiveness, and stress appraisals) mediators of the relationship between attachment security and skin barrier recovery. Finally, based on prior work examining gender differences in the relationship between adult attachment and cortisol responses to interpersonal discussions (e.g., Brooks et al., 2011; Powers et al., 2006), and the purported relationship between elevated glucocorticoid levels and delayed skin barrier recovery (Choi et al., 2006), we explored potential gender differences in the current study. However, neither attachment theory nor the existing empirical literature provided a clear rationale for making specific gender-based predictions.

## 2. Methods

### 2.1. Participants

We recruited 34 healthy couples aged 18 to 44 from the local community surrounding UCLA through flyers and online advertisements. Couples were required to have been dating for at least 3 months and spend the night with each other at least 4 nights per week. Exclusion criteria included pregnancy, medical conditions or medications with obvious immunological, dermatological, or endocrinological consequences, allergies to tape or other adhesives, smoking, and excessive caffeine or alcohol use. Women were not scheduled around their menstrual cycle stage, and we did not exclude women who were taking hormone-based contraception. A total of 33 heterosexual couples and 1 lesbian couple participated in the study. The final sample included 33 men and 35 women, mean age of 22.43 years ( $SD = 3.88$ , range 18 – 34), who had been dating on average 2.02 years ( $SD =$

1.64, range 0.29 – 6.25). The sample was 31% white, 37% Asian/Pacific Islander, 25% Latino/a, and 6% black. Most participants had some college education (53%), or received a college degree (43%), and 4% graduated from high school only.

## 2.2. Procedures

Couples participated in two visits within 7 days of each other, which were identical except for the discussion content (personal concern vs. problem-solving) and the tape-stripped arm (dominant first, non-dominant second). All sessions began at 12:30 PM to minimize the influence of diurnal variations in cortisol. Couples were asked to refrain from meals, strenuous exercise, drinking alcohol, and drinking caffeinated beverages one hour before their appointment. We also collected cardiovascular measures from one member of each couple, but given the small sample size ( $n = 34$ ), we did not examine these measures in relation to skin barrier recovery, and further details will not be provided here.

Figure 1 shows a timeline of the study. After providing informed consent, couples completed self-report measures for 30 min, allowing them to adapt to the laboratory setting. After the 30 min adaptation period, baseline salivary cortisol samples were obtained from both partners. Following this, baseline skin measurements were obtained and the skin barrier was disrupted. After skin disruption a second saliva sample was obtained from both partners. Couples then received detailed instructions for the discussion task (either the personal concern or problem-solving discussion). Order of discussions was counterbalanced such that half of the couples completed the problem-solving discussion during the first visit, and half completed the problem-solving discussion during the second visit. After completing the discussion, participants provided a second salivary cortisol sample (40 min post discussion onset) and completed self-report measures. Additional skin measurements were obtained from the disrupted sites (60, 90, and 120 min post skin disruption) and a final salivary cortisol sample was obtained (90 min post discussion onset). All procedures were approved by the UCLA Institutional Review Board, in accordance with federal, state, and institutional regulations concerning the protection of human subjects in research.

**2.2.1. Discussion tasks**—In both discussions, one partner was randomly selected to lead a discussion for 10 min on his or her selected concern/problem, followed by the other partner. The experimenter helped the couple determine the most suitable topics for discussion (described below), and explained that partners were “free to respond in any way you wish” when discussing the other partner’s concern/problem. Partners were intentionally not instructed to respond in a specific way, to allow for more naturalistic discussions. During the discussions, the interviewer left the room, and couples were monitored through hidden audio/video recording.

For the *personal concern* visit, each participant was asked to discuss something he/she would like to change about him/herself with their partner for 10 min (Pasch and Bradbury, 1998). Participants were asked to generate potential topics using a short questionnaire. The most frequently selected personal concern topics included wanting to exercise more (25%), improve time management (16%), perform better in school/work (11%), manage stress better, (9%), and spend more time with friends (9%). Additional topics included wanting to make more money, maintain regular spiritual/religious practice, getting a promotion, or improving relationships with family.

For the *problem-solving* visit, each partner was instructed to discuss a specific problem in their relationship for 10 min (Roberts et al., 2007). The experimenter assisted each partner with choosing a problem, based on responses to a questionnaire that listed several common relationship problems (Doss and Christensen, 2006). The most frequently selected problems were uncertainty about the future of the relationship (30%), feeling like the partner does not

listen well (23%), problems with parents or family members (17%), partner is too critical or demanding (15%), and not spending enough time together (15%).

## 2.3. Biological measures

**2.3.1. Skin barrier recovery**—Tape-stripping is commonly used in dermatological research to disrupt the skin barrier (Fluhr et al., 2006). Baseline skin barrier function was measured by obtaining baseline readings of transepidermal water loss (TEWL) using an evaporimeter (cyberDERM, Cortex DermaLab; Media, PA) which measures the vapor pressure gradient in the air layers close to the skin surface (Grove et al., 1999). TEWL indicates the skin's ability to prevent water loss from the interior layers. Increased TEWL reflects decreased barrier function, and decreasing TEWL following disruption indicates increasing barrier recovery.

The evaporimeter probe was touched to skin on the palm side of the forearm at three 2.5 cm<sup>2</sup> sites between 4 and 10 cm below the inside of the elbow for 1-2 min to obtain baseline measurements. A 5.1 cm × 2.5 cm area containing two of the three sites was disrupted or “stripped,” while the remaining 2.5 cm<sup>2</sup> area was left undisturbed. Measurements of the undisturbed control site indicated TEWL levels in non-disrupted skin. Next, cellophane tape (3M tape description) was applied repeatedly (6-60 times) to the disrupted site to remove the superficial layer of dead skin cells. Tape-stripping was stopped when TEWL level was elevated from an average basal level of 7.4 g/m<sup>2</sup>h (*SD* = 1.66) to at least 20 g/m<sup>2</sup>h at the disrupted site, or a maximum of 60 strips (Ghadially et al., 1995). Additional TEWL measurements were taken at 1 h, 1.5 h, and 2 h after barrier disruption. Percent recovery at each timepoint was the primary dependent variable, and was computed using the following equation (Altemus et al., 2001; Denda and Tsuchiya, 2000), in which greater values reflect greater skin barrier recovery:

$$\% \text{ recovery}_t = \frac{TEWL_{\text{after tape-stripping}} - TEWL_t}{TEWL_{\text{after tape-stripping}} - TEWL_{\text{baseline}}} \times 100$$

**2.3.2. Salivary cortisol**—Saliva samples were collected at four timepoints during each laboratory session: baseline, after tape-stripping and just before receiving instructions for the discussion task, 40 min post discussion onset, and 90 min post discussion onset. Saliva was collected using Salivettes (Sarstedt 1534, Sarstedt Inc., Newton NC), which were stored in a -20° C freezer until assay. Cortisol levels were determined by a commercially available chemiluminescence immunoassay (IBL Hamburg, Germany) at the Biological Psychology laboratory at the Technical University of Dresden in Dresden, Germany. Because the novelty of the laboratory environment can contribute to a cortisol response, only the last three of the four cortisol values were integrated into a single metric measure by computing area under the curve with respect to ground (*AUC<sub>g</sub>*), which was used in subsequent analyses to assess cortisol responses to the discussion (Pruessner et al., 2003).

## 2.4. Self-report measures

**2.4.1. Attachment anxiety and avoidance**—The 36-item Experiences in Close Relationships - Revised (ECR-R) measure was used to assess individual differences in attachment (Fraley et al., 2000). Due to experimenter error, complete anxiety and avoidance ratings were available for 32 of the 34 couples. The ECR-R assesses the two primary dimensions of attachment: anxiety and avoidance. The anxiety dimension reflects the extent to which an individual is afraid of interpersonal rejection and abandonment, and is assessed with items like, “I worry that romantic partners won't care about me as much as I care about them” (women's  $\alpha = .93$ , men's  $\alpha = .89$ ) The avoidance dimension reflects the extent to

which an individual is comfortable with closeness and intimacy, and is assessed with items like “I prefer not to show a partner how I feel deep down” (women's  $\alpha = .89$ , men's  $\alpha = .93$ ). Participants were instructed to think about how they generally experienced romantic relationships, not just the current relationship, and to respond to each statement by indicating how much they agreed or disagreed with it. Items were rated on a scale from 1 (disagree strongly) to 7 (agree strongly). We computed anxiety ( $M = 2.75$ ,  $SD = 1.06$ ) and avoidance ( $M = 2.37$ ,  $SD = 0.90$ ) scores for each participant. The sample means were comparable to normative data (Sibley et al., 2005). Anxiety and avoidance were modestly correlated ( $r = .43$ ,  $p = .00$ ) in our sample, comparable to recent meta-analytic findings using the ECR-R (Del Giudice, 2011). Typically, small differences in attachment scores, with higher anxiety ratings among women and higher avoidance among men are observed in the literature (Del Giudice, 2011). Anxiety and avoidance ratings did not differ between male and female partners within couples, anxiety  $F(1, 30) = 0.22$ ,  $p = .64$ , avoidance  $F(1, 30) = 0.01$ ,  $p = .91$ .

**2.4.2. Discussion ratings**—Participants completed ratings of current affect, stress appraisals, and ratings of partner supportiveness after the discussions were completed. To measure current *affect*, participants rated the degree to which they felt, at the current moment, a list of positive and negative emotion words on a 0 (not at all) to 6 (very much) scale. Because interpersonal emotions may have greater salience given the context of the discussions, we included both self-focused and interpersonal emotions. Positive emotions included four self-focused emotion words (cheerful, enthusiastic, happy, lively), and five interpersonal emotion words (admiration, affection, gratitude, proud of partner, touched). Negative emotions included four self-focused emotion words (ashamed, embarrassed, guilty, unhappy, sad), and three interpersonal emotion words (disappointment, rejected, resentment). Ratings were averaged across all positive words ( $\alpha = .91$ ), all negative words ( $\alpha = .90$ ), and the smaller subset of positive-interpersonal ( $\alpha = .87$ ) and negative-interpersonal ( $\alpha = .80$ ) words.

*Stress appraisals* were assessed with three items measuring perceptions that the discussion was stressful, challenging, and threatening from a 1 (not at all) to 7 (very much) scale (women's  $\alpha = .69$ , men's  $\alpha = .83$ ). *Supportiveness* ratings involved a 10-item modified form of the social support effectiveness scale (Rini and Dunkel Schetter, 2010; Rini et al., 2006), which quantitatively assesses the extent to which the quality of emotional and informational support provided by a partner meets an individual's needs, and accounts for the potential costs of receiving support. Participants were told that emotional support involves having “someone to listen to and understand our feelings or to show us affection and concern” and were asked questions like, “If/when your partner attempted to give you emotional support during the discussion, how good was the match between the amount of support he/she provided and the amount you wanted?” For informational support, participants were asked questions like, “If you needed advice or information from your partner during the discussion, how often was it difficult to get?” Items were rated on a 5 point scale, where 1 indicated “Not at all” and 5 indicated “Extremely.” We combined the emotional ( $\alpha = 0.92$ ) and informational ( $\alpha = 0.88$ ) support subscales to create an index of overall partner supportiveness ( $\alpha = 0.95$ ). The average partner supportiveness score was 3.76 ( $SD = 0.88$ ), which corresponds to a rating of “good” or “quite a bit.”

## 2.5. Data analyses

**2.5.1. Data screening**—Outlier data points (2 out of 509) that were outside  $\pm 3$  *SD* from the mean were removed from the data, and remaining data points within that range were retained. One participant showed an unusual pattern of recovery during the problem discussion visit ( $> 200\%$  recovery at 1 h, which increased during the session) and we excluded that individual's data. One same-sex (female) couple participated in the study, and

their data was excluded from the primary analyses which required distinguishable dyads (male and female). Including the couple in the analyses did not change the pattern of results (data not shown).

**2.5.2. Modeling change in recovery**—We used multilevel modeling (PROC MIXED in SAS, SAS Institute, Inc., Cary, NC) for our primary analyses of skin barrier recovery, which accounted for the dyadic and interdependent nature of our data. Our primary analyses used the “two intercepts” approach, modeling parameters simultaneously for male and female partners (Raudenbush et al., 1995). . Therefore, throughout the results section, we describe results separately for women followed by results for men.

For simplicity, we present a model of change for individuals, followed by the two-intercept model. The model for change at the measurement level (level-1), based on visual inspection of the data and fit indices with different models of change, was as follows:

$$\% \text{ recovery}_{ij} = \pi_{0ij} + \pi_{1ij}(\text{time}) + \pi_{2ij}(\text{time}^2) + e_{ij} \quad (1)$$

where % recovery for person *i* at day *j* and time *t* was a function of an initial value  $\pi_{0j}$ , a linear slope  $\pi_{1j}$  for time (h since tape-stripping), a quadratic slope  $\pi_{2j}$  to accommodate the curvilinear shape of skin barrier recovery data over time (Robles, 2007), and within-subjects variance  $e_{ij}$ . Initial skin barrier recovery after tape-stripping ( $\pi_{0ij}$ ) was equal to zero across days and participants and was specified as fixed in all models. Measurement occasions were nested within days (level-2), by including fixed parameters testing the effect of visit on linear and quadratic slopes (effects coded as problem discussion = -1, personal concern = 1). Effects coding allowed for interpreting the level-1 intercepts and slopes as averages between the two visits.

We modeled individual at level-3, and linear effects of time were allowed to vary between individuals (models with both linear and quadratic effects specified as random resulted in a variance component matrix that was not positive definite). Attachment anxiety and avoidance were included as level-3 predictors of slopes only, since the intercept values were always zero across participants. Beyond predicting change in recovery over time, anxiety and avoidance were included as predictors of visit effects, providing a cross-level interaction that allowed for examining whether the effects of attachment on skin barrier recovery depended on the discussion taking place that day. These models did not include the anxiety x avoidance interaction for two primary reasons – small sample size, and limited generalizability. Our restricted ranges for anxiety and avoidance scores limited our ability to draw conclusions about the various attachment prototypes (fearful, dismissing, preoccupied, and secure) derived from the anxiety x avoidance interaction.

Our final model, with couples at level-3 and separate parameters for males and females (with male and female dummy coded) is illustrated below in single equation form:

$$\begin{aligned} \% \text{ recovery}_{ij} &= [ \text{male} ] \left[ \gamma_{000} + \gamma_{100}(\text{time}) + \gamma_{110}(\text{day} \times \text{time}) + \gamma_{200}(\text{time}^2) + \gamma_{100}(\text{day} \times \text{time}^2) + \gamma_{101}(\text{anxiety} \times \text{time}) + \gamma_{111}(\text{anxiety} \times \text{day} \times \right. \\ &+ [ \text{female} ] \left[ \gamma_{000} + \dots + e_{ij} \right] \end{aligned} \quad (2)$$

The Satterthwaite approximation for denominator degrees of freedom, recommended for smaller sample sizes and for dyadic data analyses (Kenny et al., 2006), was used for all analyses. Linear slopes were allowed to covary between male and female partners. In addition, we imposed a first-order auto-regressive matrix on the level-1 residuals (AR[1]).



Gender differences in parameter estimates were tested by dividing the difference between the two parameters by the standard error of the difference,

$\sqrt{Var_{male} + Var_{female} - 2cov(male, female)}$ , which yielded a  $t$ -statistic. In tables we report parameter estimates, standard errors, degrees of freedom,  $t$ -statistics, and  $p$ -values, while in the text for brevity we report parameter estimates,  $t$ -statistics, and  $p$ -values unless noted otherwise.

**2.5.3. Exploring interactions and mediators**—Significant interactions were further explored using online tools for interpreting 2-way and 3-way interactions for mixed models ([www.quantpsy.org](http://www.quantpsy.org); Preacher et al., 2006). The tools allow for determining “regions of significance,” representing the range of values for one variable (e.g., attachment anxiety) where the effects of the other variable (linear effects of time) on the dependent variable (skin barrier recovery) are significant. The online tools also allow for computing the statistical significance simple slopes at specific values of attachment anxiety/avoidance. Mediation was tested using procedures in which multiple multilevel model equations and/or ordinary least squares regression models provide unstandardized parameter estimates of the relationship between the predictor variable and mediator ( $\beta_a$ ), and the mediator and dependent variable ( $\beta_b$ ) (Krull and MacKinnon, 2001). The significance of the indirect effect  $\beta_a\beta_b$  was then computed using the Sobel test (Baron and Kenny, 1986).

### 3. Results

#### 3.1. Affect ratings, stress appraisals, and supportiveness ratings

To provide context for how partners responded to the discussions, and how attachment was related to subjective responses to the discussions, we modeled subjective responses in a 3-level multilevel model as a function of visit, order (personal concern first vs. problem discussion first), the visit x order interaction, anxiety, avoidance, and interactions between attachment and visit. We describe effects for women, followed by men.

**3.1.1. Women**—Negative emotions and negative interpersonal emotion ratings did not significantly differ between visits or order, and were not significantly related to attachment anxiety. Positive emotion ratings were higher during the personal concern discussion compared to the problem solving discussion,  $\gamma = 0.66$ ,  $t = 3.81$ ,  $p = .0003$ , and a significant visit x order interaction indicated that the difference between discussions was larger for women who had the personal concern visit first,  $\gamma = -0.61$ ,  $t = -2.38$ ,  $p = .02$ , compared to women who had the problem discussion first. Positive interpersonal emotions ratings did not differ by visits or order, and there was no significant visit x order interaction. Women with greater attachment anxiety reported fewer positive emotions across both discussions,  $\gamma = -0.44$ ,  $t = -2.76$ ,  $p = .008$ , but there was no effect for positive interpersonal emotions. Avoidance was not related to emotion ratings.

For stress appraisals, the personal concern discussion was rated as less stressful compared to the problem discussion,  $\gamma = -0.34$ ,  $t = -1.96$ ,  $p = .05$ . Higher attachment anxiety was related to greater stress appraisals across both visits,  $\gamma = 0.27$ ,  $t = 1.96$ ,  $p = .05$ . Avoidance was not related to stress appraisals.

Supportiveness ratings did not differ between visits, although there was a trend such that women rated their partner as more supportive after the personal concern discussion than after the problem discussion,  $\gamma = 0.22$ ,  $t = 1.77$ ,  $p = .08$ . Anxiety and avoidance were not related to supportiveness ratings.

**3.1.2. Men**—Negative emotions and negative interpersonal emotion ratings did not significantly differ between visits or order. Positive interpersonal emotion ratings did not differ between visits, by order, and there was no significant visit x order interaction. Men with greater attachment anxiety reported more negative emotions across both discussions,  $\gamma = 0.59$ ,  $t = 3.34$ ,  $p = .003$ , which was qualified by a significant visit x anxiety interaction,  $\gamma = -0.29$ ,  $t = -2.06$ ,  $p = .04$ . The interaction indicated that the relationship between anxiety and negative emotions was larger during the problem discussion visit compared to the personal concern visit, with a similar pattern for negative interpersonal emotions (data not shown). Anxiety was not significantly related to positive emotions or positive interpersonal emotions, and avoidance was not related to positive emotions or positive interpersonal emotions.

The personal concern discussion was rated as less stressful than the problem discussion,  $\gamma = -0.44$ ,  $t = -2.41$ ,  $p = .02$ . Higher attachment anxiety was related to greater stress appraisals across both discussions,  $\gamma = 0.69$ ,  $t = 2.80$ ,  $p = .008$ . Avoidance was not related to stress appraisals.

Supportiveness ratings did not differ between visits. Men who were higher in attachment anxiety rated their partners as less supportive during both visits,  $\gamma = -0.43$ ,  $t = -2.69$ ,  $p = .01$ . There was no association between avoidance and supportiveness ratings.

**3.1.3. Gender differences in the relationship between attachment and subjective responses**—These analyses focused on attachment anxiety only, as there were no relationships between avoidance and subjective responses. We found gender differences in the relationship between attachment anxiety and negative emotions that approached significance ( $t = 2.01$ ,  $p = .05$ ), in the direction of significant effects for men but not women (as described above).

## 3.2. Modeling change in skin barrier recovery

Parameter estimates describing change in skin barrier recovery during each visit, as described in Equation (1), are shown in Table 1. As expected, skin barrier recovery increased over time with some slowing in the rate of recovery during the course of each session. Recovery rates were similar between women and men, and did not differ by visit, as indicated by the non-significant effects of the problem discussion dummy code on linear or quadratic slopes. Linear slopes showed significant between-couple differences, and linear slopes were not correlated between members of the couple.

Changes in TEWL during the visits may be due to changes in the moisture level of the skin in general, unrelated to skin barrier recovery at the disrupted site. The undisturbed control site provides measurements of changes in TEWL in non-disrupted skin, and we found no significant change in TEWL at the control site during either visit, and no differences in TEWL between visits (data not shown). Thus, the changes in skin barrier recovery at the disrupted site were primarily due to the actual process of skin barrier recovery, rather than changes in skin hydration during the session, such as those produced by sweating.

**3.2.1. Effects of attachment on skin barrier recovery**—We found significant effects of attachment anxiety and avoidance on skin barrier recovery, and significant gender differences in the effects of attachment on skin barrier recovery. Parameter estimates based on Equation (2), as well as tests of gender differences in those parameter estimates are shown in Table 2. On average, skin barrier recovery increased by roughly 50% per hour of time, with a decrease of roughly 15% per hour of time<sup>2</sup> which contributed to the curvilinear pattern of change. Across all models described below, the overall pattern was increasing recovery over time. Figures 2 and 3 show predicted skin barrier recovery values based on

the model in equation (2), with lines representing  $\pm 1$  *SD* relative to the mean for attachment anxiety or avoidance. We first describe results for women, followed by men.

**3.2.1.1. Women:** Greater attachment anxiety was related to faster skin barrier recovery across the two visits, shown in Figure 2A. Using the online tool at [www.quantpsy.org](http://www.quantpsy.org), further exploration of the anxiety  $\times$  time and time<sup>2</sup> interaction indicated that the effect of time and time<sup>2</sup> was significant across the entire range of observed anxiety scores. Thus, greater attachment anxiety was related to larger increases in skin barrier recovery with each hr of time, with women scoring 1 *SD* above the mean for anxiety showing 14.7% greater skin barrier recovery 2 h after tape-stripping compared to women scoring 1 *SD* below the mean<sup>2</sup>. In addition, greater attachment avoidance was related to slower skin barrier recovery across the two visits, shown in Figure 2B. Women scoring 1 *SD* below the mean for avoidance showed 27.5% greater skin barrier recovery 2 h after tape-stripping compared to women scoring 1 *SD* above the mean. Further exploration of the avoidance  $\times$  time and time<sup>2</sup> interactions indicated that the effect of time and time<sup>2</sup> was significant across the entire range of observed avoidance scores, with greater avoidance associated with smaller increases in skin barrier recovery with each hr of time.

**3.2.1.2. Men:** There were no significant effects of attachment on skin barrier recovery across the two visits. Instead, there was a significant effect of anxiety in predicting change in skin barrier recovery that was different between the two visits. To further explore the interaction, we computed simple slopes for time for attachment anxiety scores  $\pm 1$  *SD* from the mean, for the personal concern and problem discussion visits separately. During the personal concern visit, the simple slope for time *differed* at -1 and + 1 *SD* from the mean for anxiety ( $\gamma = 0.78$ ,  $SE = 0.11$  vs.  $\gamma = 0.28$ ,  $SE = 0.10$ , respectively), while during the problem solving visit the simple slope for time was *similar* at -1 and + 1 *SD* from the mean ( $\gamma = 0.43$ ,  $SE = 0.011$  vs.  $\gamma = 0.48$ ,  $SE = 0.10$ , respectively). Mirroring these results, conducting separate models for each visit showed that greater anxiety was related to smaller slopes for time, and thus slower skin barrier recovery, during the personal concern visit ( $\gamma = -0.23$ ,  $t = -4.41$ ,  $p < .0001$ ) while there was no significant effect of anxiety on linear time slope during the problem discussion visit ( $\gamma = 0.03$ ,  $t = 0.41$ , *ns*). At 2 h after tape-stripping, men scoring 1 *SD* below the mean for anxiety showed 45% greater skin barrier recovery compared to men scoring 1 *SD* above the mean.

**3.2.2. Attachment and TEWL in non-disrupted skin—**The effects of attachment on skin barrier recovery could be due to effects of attachment on TEWL in non-disrupted skin. For example, individuals with greater anxiety or avoidance may show an increase in sweating during the course of the session, which would register as increased moisture loss and contribute to lower estimates of skin barrier recovery (since greater moisture loss reflects slower recovery at a wounded site). In subsequent analyses, we controlled for TEWL at the control site to determine if changes in TEWL in non-disrupted skin explained relationships between attachment and skin barrier recovery, shown in Table 3. For women, greater anxiety continued to predict faster skin barrier recovery across both visits, linear =  $-0.15$ ,  $t = 3.47$ ,  $p = .0006$ , quadratic =  $-0.05$ ,  $t = -3.24$ ,  $p = .001$ ; and greater avoidance continued to predict slower skin barrier recovery across both visits. For men, the previously trend-level effect of anxiety on skin barrier recovery across both visits became significant, qualified by a significant anxiety  $\times$  time interaction, which was in the same direction as shown in Table 2. Thus, the same pattern of effects held even after controlling for TEWL at the control site.

<sup>2</sup>For comparison, in Robles (2007), young adults who were randomly assigned to go through a non-stressful reading task showed 25.6% greater skin barrier recovery 2 h after tape-stripping compared to individuals assigned to perform the Trier Social Stress Test.

### 3.3. Testing potential mediators

**3.3.1. Women**—We next examined whether cortisol changes in response to the discussion (cortisol AUCg)<sup>3</sup> predicted skin barrier recovery, substituting cortisol AUCg as the only predictor of slopes in equation (2). Cortisol levels did not predict skin barrier recovery across visits, and the relationship between cortisol levels and skin barrier recovery within each visit was not significant.

Then, we tested whether subjective experience during the discussion mediated the effects of attachment on skin barrier recovery. For the effect of attachment anxiety on skin barrier recovery, positive emotions and stress appraisals were candidate mediators. Although greater positive emotion ratings were related to smaller linear time slope across both visits ( $\gamma = -0.08$ ,  $t = -2.19$ ,  $p = .03$ ), and thus to slower skin barrier recovery, the estimate of the indirect effect was not significant,  $\beta_a\beta_b = 0.02$ ,  $t = 1.09$ ,  $p = .27$ . Attachment anxiety remained a significant predictor of skin barrier recovery ( $\gamma = 0.08$ ,  $t = 2.12$ ,  $p = .03$ ), while positive emotion ratings during the visits were no longer significant predictors of recovery. Thus, positive emotions did not explain the relationship between anxiety and recovery. Higher stress appraisals were also not significantly related to skin barrier recovery and were not explored further as a potential mediator of the effect of women's anxiety.

**3.3.2. Men**—Cortisol levels during the visits did not predict skin barrier recovery averaged across visits. Instead, there was a trend-level interaction of cortisol x time x visit,  $\gamma = -0.07$ ,  $t = -1.81$ ,  $p = .07$ . To explore this interaction further, we modeled the effects of cortisol on skin barrier recovery for each visit separately. Cortisol levels during the problem discussion visit were not significantly related to skin barrier recovery. However, greater cortisol levels during the personal concern visit predicted slower skin barrier recovery,  $\gamma = -0.14$ ,  $t = -3.32$ ,  $p = .001$ ,  $\gamma = 0.06$ ,  $t = 3.05$ ,  $p = .003$ . Given that attachment anxiety during the personal concern visit was related to slower skin barrier recovery, and having established that the potential mediator (total salivary cortisol production during the personal concern discussion visit) was related to skin barrier recovery, we conducted additional analyses to determine whether the effect of attachment anxiety was explained by salivary cortisol production. Greater attachment anxiety was marginally related to greater total cortisol production during the personal concern discussion visit, in the expected direction, unstandardized  $\beta = 0.06$ ,  $SE = 0.03$ ,  $t = 1.75$ ,  $p = .09$  (standardized  $\beta = .31$ ), which was used to compute an indirect effect  $\beta_a\beta_b = -0.0005$  ( $SE = 0.005$ ),  $t = -1.31$ ,  $p = .19$ . Taken together, salivary cortisol production did not significantly mediate the relationship between attachment anxiety and skin barrier recovery in men during the personal concern visit, which was further evident by the fact that the coefficient for the effect of anxiety on the linear time slope remained significant ( $\gamma = -0.12$ ,  $t = 2.48$ ,  $p < .01$ ).

Regarding subjective responses, for the effect of anxiety on skin barrier recovery during the personal concern discussion, negative emotions, including negative interpersonal emotions, were candidate mediators. In addition, given that greater men's anxiety was related to lower ratings of supportiveness and higher stress appraisal ratings across both visits, they were also tested as potential mediators. For men's anxiety, negative emotions (including negative interpersonal emotions), perceptions of supportiveness, and stress appraisals were not significantly related to skin barrier recovery during the personal concern discussion and were not explored further as potential mediators. Thus, we found no evidence that subjective experience mediated the effects of attachment on skin barrier recovery.

<sup>3</sup>Cortisol AUCg did not differ between men and women ( $F < 1$ ). The mean log AUCg for men was 2.72 ( $SE = 0.03$ ) and the mean log AUCg for women was 2.71 ( $SE = 0.03$ ). There was a trend for greater cortisol AUCg during the problem discussion task (mean log AUCg = 2.74,  $SE = 0.02$ ) compared to the personal concern task (mean log AUCg = 2.69,  $SE = 0.02$ ),  $F(1,31) = 3.17$ ,  $p = .09$ .

## 4. Discussion

In this study, we demonstrated individual differences in the attachment system are related to the skin's ability to heal. This work adds to the larger literature on stress and the skin by suggesting associations between individual differences in trait characteristics and the skin's ability to heal during stressors (Robles et al., 2009). Contrary to our predictions, skin barrier recovery did not differ between the personal concern and problem solving discussions. However, consistent with our predictions, greater attachment avoidance among women was related to slower recovery across discussions, and greater attachment anxiety among men was related to slower recovery during the personal concern discussion. Unexpectedly, for women greater attachment anxiety predicted *faster* skin barrier recovery across both discussions. Importantly, the pattern of results held after controlling for control site TEWL, suggesting that our results were not confounded by systemic changes in TEWL during the course of the session. Our findings were also observed in a relatively young, healthy sample of satisfied dating couples, and the magnitude of differences in recovery between individuals scoring  $\pm 1$  *SD* from the mean for anxiety/avoidance was similar to differences in magnitude when exposed to an acute laboratory stressor (Robles, 2007).

We found no differences in skin barrier recovery between the personal concern and problem discussion visits. In previous work, blister wound healing was slower following a problem discussion compared to a personal concern discussion (Kiecolt-Glaser et al., 2005). Thus, we initially expected the problem discussion to act in a similar manner as an acute stressor, delaying skin barrier recovery, compared to the personal concern discussion. At the same time, we note that our sample consisted of young couples dating for a relatively short period of time compared to married couples in the Kiecolt-Glaser et al. (2005) study, who were married an average of 12.6 years. Therefore, the problems under discussion in marital interaction studies may reflect larger, more chronic problems in the relationship (Robles and Kiecolt-Glaser, 2003), and thus the marital discussions may have been more aversive compared to our dating couples, who had a considerably shorter relationship history. Wound type may also play a role; the more severe blister wounds, with considerably more involvement by the immune system, may be more sensitive to psychosocial factors compared to the tape-stripping wounds in this study.

Despite similar rates of skin barrier recovery across visits, greater attachment avoidance in women was related to slower skin barrier recovery across both visits. Individuals with high attachment avoidance are less comfortable with closeness and rely less upon others for support (Collins and Feeney, 2000). Moreover, such individuals regulate emotion by distancing themselves from others (Mikulincer et al., 1993). The laboratory setting in which couples spend 3 - 4 h in each other's presence prevents physical distancing, making it difficult for high avoidant women to escape, particularly during the discussions. Thus, one explanation for why high avoidance in women was related to slower skin barrier recovery across both discussions is that the inescapable settings were experienced as unpleasant, threatening, or aversive. However, we did not find evidence that discussion-related HPA activity explained avoidance-related delays in skin barrier recovery. In addition, high avoidance in women was not related to elevated negative emotions or stress appraisals, though other studies suggest that high avoidant individuals may have poor recognition of physiological signs of distress or anger, and thus may underreport their distress (Diamond et al., 2006; Mikulincer, 1998). Finally, other potential unmeasured mechanisms may explain such relationships, such as sympathetic activity. Notably, greater anxiety and/or avoidance are related to elevated sympathetic activity; including elevated skin conductance levels during problem-solving discussions with a romantic partner (Roisman, 2007b) and laboratory stressors (Diamond et al., 2006), and increased sympathetic activity in the skin is associated with delayed wound healing in animal models (Souza et al., 2005).

Among men, we found an effect of anxiety on skin barrier recovery during the personal concern discussion, which was designed to elicit support from one's partner. High attachment anxiety is related to less satisfaction with support (Collins and Feeney, 2004), which was consistent with our findings for supportiveness ratings by men. Discussions involving emotional and informational support may be more threatening to men with high anxiety because inadequate support provision may be construed as evidence of their partner's general lack of concern and care for their well-being (Kane et al., 2012; Murray et al., 2006). At the same time, supportiveness ratings did not explain the relationship between anxiety and skin barrier recovery for men. While problem solving discussions are usually associated with increased physiological stress responses among married couples, in dating couples, problem solving may be an opportunity to increase closeness, which may explain why no relationships between attachment anxiety and skin barrier recovery were observed among men during the problem discussion day.

Unexpectedly, greater anxiety among women predicted faster skin barrier recovery across both discussions. Greater attachment insecurity is generally related to elevated reactivity in the neuroendocrine mechanisms that may mediate skin barrier recovery. Thus, how might greater reactivity predict faster recovery? We previously observed that greater systolic blood pressure increases to an acute stressor, indicative of greater sympathetic reactivity, predicted faster skin barrier recovery (Robles, 2007). In addition, skin barrier recovery is directly mediated by immune mechanisms, such as increases in localized inflammatory mediators in the skin following skin barrier disruption. While stress is broadly viewed as suppressing the immune system, a sizeable literature in animals, and to a lesser degree in humans, shows that acute stressors, particularly over a short-term period of minutes to hours, can enhance immune function, particularly in the skin (Dhabhar, 2009). For example, briefly restraining mice for 2.5 h increased inflammation in skin induced by exposure to a skin irritant (Viswanathan et al., 2005). In addition, the immune-enhancing effects of acute stressors are mediated by the same HPA and autonomic changes that are traditionally viewed as contributing to immune suppression (Dhabhar, 2009).

Moreover, animal research on social interactions and inflammation suggests that repeated experiences of social threat (e.g., defeat by an aggressive animal, or disruptions in social hierarchies) can increase HPA axis activity, and at the same time decrease glucocorticoid sensitivity in target cells, preventing the HPA axis from suppressing inflammatory responses (Avitsur et al., 2006). This pattern is considered a "preparative" response that primes a rapid inflammatory response to injuries that may occur during acute stressors. Extending this conceptualization to attachment and skin barrier recovery, faster skin barrier recovery in women with high attachment anxiety may be a preparative response to expected social injury (inadequate support or rejection from an intimate partner). We note however, that demonstrating such a "preparative" response requires demonstrating elevated HPA axis responses and/or reduced glucocorticoid sensitivity at the level of the skin in women with elevated attachment anxiety. Unfortunately, the former was not observed in previous work (Powers, Pietromonaco, Gunlicks, & Sayer, 2006), including a prior report from our current sample (Brooks, Robles, & Dunkel Schetter, 2011). At the same time, in chronically stressed populations, glucocorticoid insensitivity can occur even in the absence of elevated HPA activity (Miller et al., 2008). Glucocorticoid sensitivity can be studied in the skin (Ebrecht et al., 2000), but has not been included in biobehavioral research.

Unlike women with high attachment anxiety, a preparative response to social threat would not be expected to operate in women with high attachment avoidance. High avoidance is associated with greater self-reliance, less need or expectation for support from others, and less comfort with intimacy. Moreover, during personal concern discussions, individuals high in avoidance tend to not seek support, minimizing the possibility of having their partners

provide support (Collins and Feeney, 2000). Thus, partner interactions are viewed less as a potential threat to self (a social injury, thus requiring a preparative response), but rather, as described above, an uncontrollable, inescapable stressor.

A key unanswered question raised by this study is why the relationship between attachment anxiety and skin barrier recovery was in an opposite direction for men and women. Relatively few studies have explicitly tested gender differences in the relationship between attachment anxiety and physiological responses. Greater attachment anxiety predicted greater cortisol reactivity during problem discussions in men, but not women (Brooks et al., 2001; Powers et al., 2006), and greater anxiety was related to lower electrodermal reactivity to several standardized laboratory stressors in women, but not men (Diamond et al., 2006). Unfortunately, existing theories have not addressed such gender differences, which is a key direction for future work. One possibility is that men and women with greater attachment anxiety subjectively experience relationship discussions in different ways. For example, in our sample men with greater attachment anxiety reported greater negative emotions following the discussions. In contrast, women with greater attachment anxiety did not report greater negative emotions, but did report lower positive emotions. Perhaps nonconscious antecedents of observed affect ratings that activate the attachment behavioral system but occur too quickly to report, such as cognitive appraisals, differed between highly anxious men and women and contributed to different downstream effects on skin barrier recovery. Another possibility, based on the literature on social support is that giving and receiving support (typically expected during personal concern discussions) may be more normative for women compared to men, due to gender differences in socialization and acculturation (Cross and Madson, 1997; Helgeson, 1994). For example, socialized gender roles may lead women to be accustomed to, and more comfortable with, providing and receiving support, whereas men socialized with more traditional masculine roles may be uncomfortable with support needs and expectations. Thus, being in a position of receiving and providing support may be threatening for highly anxious men in a way that differs from highly anxious women.

This study is the first to demonstrate that elevated cortisol responses to social interactions predict slower skin barrier recovery in humans, with greater cortisol production during the personal concern visit was related to slower skin barrier recovery in men. Prior acute stress studies did not find that elevated cortisol production was significantly related to skin barrier recovery (Altemus et al., 2001; Robles, 2007). Cortisol production did not mediate the relationship between anxiety and skin barrier recovery, although this may be due to low power to detect such effects, as anxiety did show a small-moderate (though non-significant) relationship with cortisol production<sup>4</sup>.

It is not clear why the relationship between cortisol production and skin barrier recovery only emerged in the personal concern visit and not the problem discussion visit, and why such effects were only found in men and not women. One of the major challenges to studying glucocorticoids as a potential mediator of relationships between psychosocial factors and skin function is that cortisol levels circulating in saliva or blood may not reflect levels of cortisol resident in the skin, and there are no current methods for examining acute elevations of skin-resident cortisol (Robles and Carroll, 2011). In addition, hair follicles contain all the molecular machinery necessary for synthesizing cortisol (Ito et al., 2005). Thus, even if glucocorticoids have effects on skin barrier recovery, the source of those glucocorticoids, and how they are stimulated by signals coming from the brain, still remains

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<sup>4</sup>In a previous paper, we found that in men, greater attachment anxiety was significantly related to elevated cortisol reactivity (but not cortisol recovery) during the problem discussion (Brooks, Robles, & Dunkel Schetter, 2011). In that study, reactivity and recovery were operationally defined as changes from baseline, and changes from peak, respectively. In the current paper, we used an integrated metric, AUCg, which may explain the trend-level associations observed in this study.

unclear. More generally, psychological and biological mediators have not been clearly identified in research to date on skin barrier recovery in humans (Robles and Carroll, 2011).

The limitations of this study suggest directions for future research. We observed relationships between attachment and skin barrier recovery in a small sample of healthy, satisfied couples, where the distribution of anxiety and avoidance was skewed towards greater attachment security. Moreover, the severity and duration of problems in the relationship were minimal. Besides increasing sample size, future work should incorporate couples with a wider distribution of attachment orientations, and a wider range of relationship satisfaction and strain. In addition, we did not assess skin barrier recovery outside the context of relationship discussions, such as a baseline day, which may be useful. Thus, the degree to which attachment predicts skin barrier recovery more generally is untested. For example, might we expect similar relationships if participants came to the lab alone, and not subjected to any types of stressors? Future work should incorporate measures of mediating mechanisms at the level of the skin, such as proinflammatory cytokine levels, or transcription of genes related to skin barrier recovery and wound healing. Finally, most work on attachment and objectively assessed physical health outcomes like skin barrier recovery has been conducted in adults. Given that the attachment system begins operating and developing in infancy and early childhood with observable neuroendocrine effects (Gunnar and Donzella, 2002), future work should consider examining relationships between attachment disruptions (e.g., separations, harsh rearing) and individual differences in attachment styles at early ages.

These findings provide additional evidence that relationship factors are associated with restorative processes in the largest organ in our body, the skin. Moreover, we provide the first preliminary evidence that individual differences in the attachment behavioral system are related to restorative biological processes, further expanding the realm of biological and behavioral functions of the attachment system. In addition to establishing one potential mechanism (among many) through which individual differences in the attachment system affect health, these data also support a broader need for future research to focus on factors, particularly gender-related moderators and mediators (Kiecolt-Glaser & Newton, 2001), that magnify the positive and negative effects of relationships on physiology and clinically relevant health outcomes.

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## Abbreviations

<b>AUCg</b>	area under the curve with respect to ground
<b>ECR-R</b>	Experiences in Close Relationships – Revised
<b>HPA</b>	hypothalamic-pituitary-adrenal
<b>TEWL</b>	transepidermal water loss



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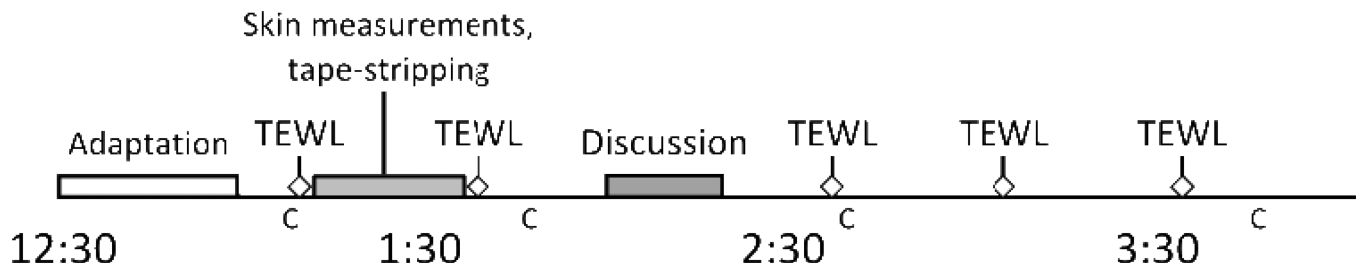
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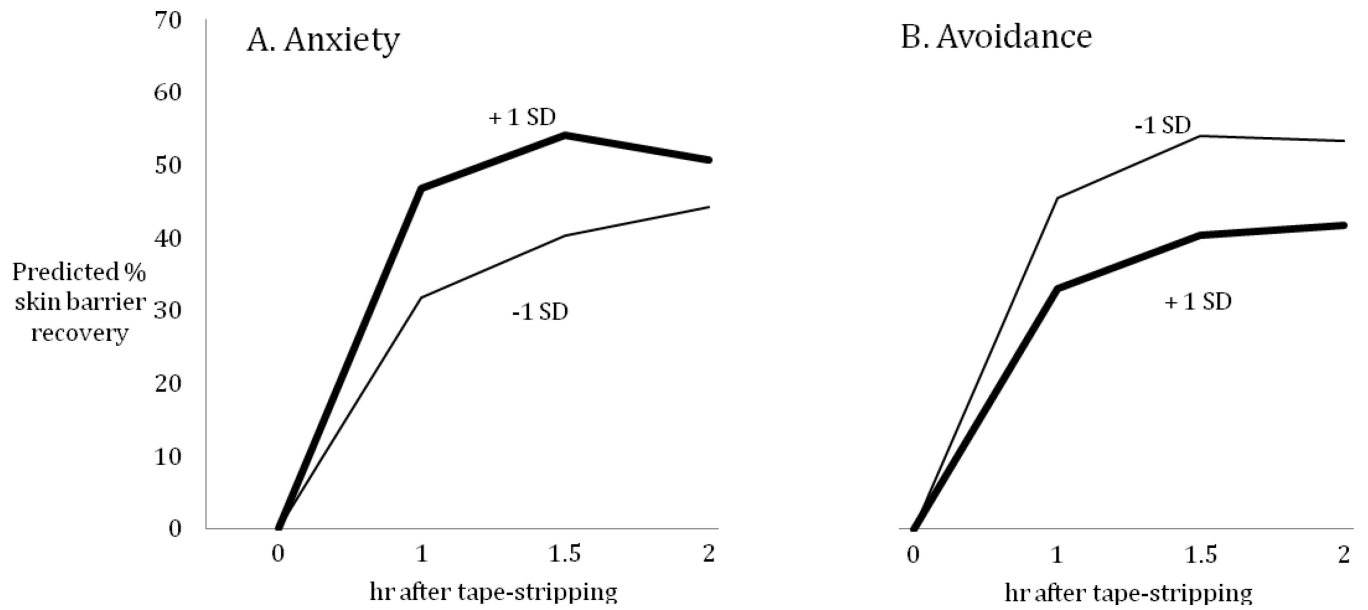
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### Highlights

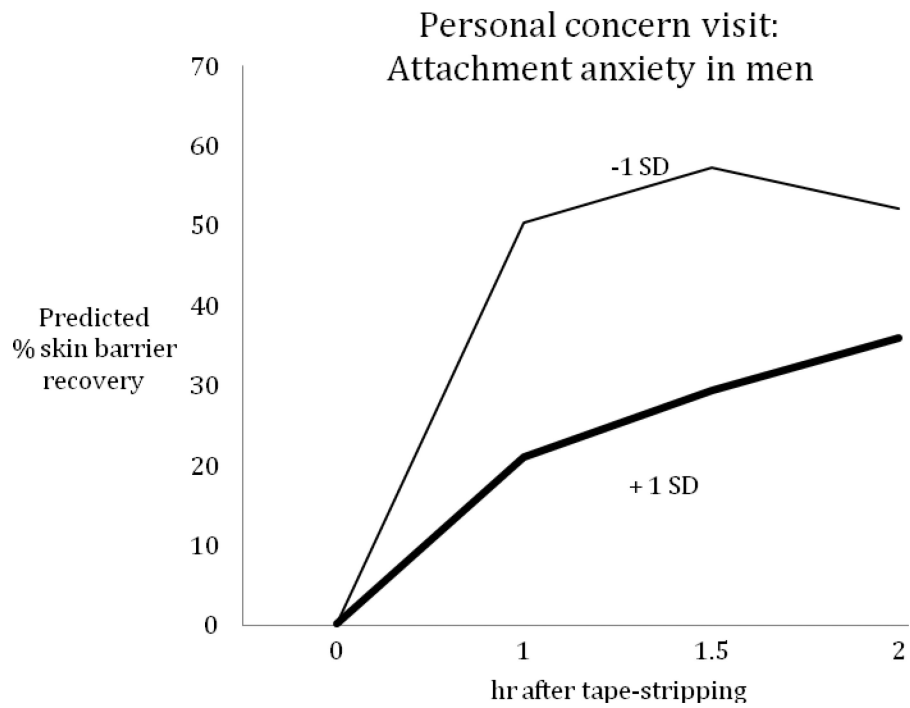
- Attachment security in relationships is related to the skin's ability to heal
- In women, greater attachment avoidance is related to slower recovery
- In men, greater attachment anxiety is related to slower recovery
- Unexpectedly, in women greater attachment anxiety is related to faster recovery



**Figure 1.** Timeline of study events. C = salivary cortisol. TEWL = transepidermal water loss



**Figure 2A-B.** Predicted skin barrier recovery averaged across visits, as a function of anxiety and avoidance in women. Thick lines represent individuals scoring +1 SD from the mean, thin lines represent individuals scoring -1 SD from the mean.



**Figure 3.** Skin barrier recovery during the personal concern visit, as a function of anxiety in men. Thick lines represent individuals scoring +1 SD from the mean, thin lines represent individuals scoring -1 SD from the mean.



Table 1

Parameter estimates predicting change in skin barrier recovery

Parameters	Women				Men				Gender difference	
	Estimate	SE	df	t	p	Estimate	SE	df	t	p
Fixed effects										
Intercept, $\gamma_{000}$	-0.002	0.02	326	-0.08		0.002	0.02	320	0.10	-
Time, $\gamma_{100}$	0.53	0.04	340	12.11	<.0001	0.50	0.04	354	11.24	<.0001
Visit, $\gamma_{110}$	0.03	0.04	419	0.85	-	0.04	0.04	422	0.96	-
Time <sup>2</sup> , $\gamma_{200}$	-0.15	0.02	405	-7.52	<.0001	-0.14	0.02	397	-6.69	<.0001
Visit, $\gamma_{210}$	-0.02	0.02	421	-0.82	-	-0.02	0.02	410	-0.79	-
Variances/Covariances										
	Estimate	SE	z	p		Estimate	SE	z	p	
Time	0.007	0.003	2.76	.003		0.005	0.002	2.55	0.005	
Between partners covariance	0.05	0.26	0.19	ns		-	-	-	-	
Between measures AR(1) covariance	0.35	0.05	7.78	<.0001		-	-	-	-	
Within-subject variance, $e_{ij}$	0.03	0.003	12.51	<.0001						

Note. Visit was effects coded, personal concern = 1, problem discussion = -1. AR(1) = first-order autoregressive. Only  $p$ -values < .10 shown.  $N = 33$  couples.

**Table 2**

Parameter estimates predicting change in skin barrier recovery from attachment

Parameters	Women			Men			Gender difference								
	Estimate	SE	df	t	p	Estimate	SE	df	t	p	Estimate	SE	df	t	p
Fixed effects															
Intercept, $\gamma_{000}$	0.0006	0.02	306	0.02	-	0.002	0.02	301	0.07	-	-	-	-	-	-
Time, $\gamma_{100}$	0.55	0.04	320	12.24	<.0001	0.49	0.05	329	10.70	<.0001	-	-	-	-	-
Anxiety, $\gamma_{101}$	0.13	0.04	324	3.47	.0006	-0.11	0.06	337	-1.90	.06	.0006	.0006	.0006	.0006	.0006
Avoidance, $\gamma_{102}$	-0.95	0.04	328	-2.17	.03	0.08	0.06	378	1.36	-	.02	.02	.02	.02	.02
Time <sup>2</sup> , $\gamma_{200}$	-0.15	0.02	373	-7.76	<.0001	-0.14	0.02	366	-6.50	<.0001	-	-	-	-	-
Anxiety, $\gamma_{201}$	-0.06	0.02	390	-3.28	.001	0.05	0.03	380	1.88	.06	.0009	.0009	.0009	.0009	.0009
Avoidance, $\gamma_{202}$	0.03	0.02	394	1.57	-	-0.04	0.03	372	-1.35	-	.04	.04	.04	.04	.04
Effects of visit															
Time, $\gamma_{110}$	0.03	0.04	384	0.87	-	0.04	0.04	389	0.92	-	-	-	-	-	-
Anxiety, $\gamma_{111}$	0.0095	0.04	385	0.27	-	-0.14	0.05	381	-2.52	.01	.02	.02	.02	.02	.02
Avoidance, $\gamma_{112}$	-0.06	0.04	383	-1.52	-	0.06	0.05	390	1.17	-	.06	.06	.06	.06	.06
Time <sup>2</sup> , $\gamma_{210}$	-0.02	0.02	378	-0.91	-	0.02	0.02	373	0.70	-	-	-	-	-	-
Anxiety, $\gamma_{211}$	0.0095	0.02	385	0.55	-	0.05	0.03	374	1.90	.06	-	-	-	-	-
Avoidance, $\gamma_{212}$	0.02	0.02	387	1.12	-	-0.02	0.03	368	-0.74	-	-	-	-	-	-
Variances/Covariances	Estimate	SE	z	p		Estimate	SE	z	p		Estimate	SE	z	p	
Time	0.007	0.003	2.60	.005		0.005	0.002	2.37	.009		-	-	-	-	-
Between partners covariance	-0.09	0.28	-0.35	-		-	-	-	-		-	-	-	-	-
AR(1) covariance	0.34	0.05	7.12	<.0001		-	-	-	-		-	-	-	-	-
Within-subject variance, $e_{ij}$	0.03	0.003	12.13	<.0001		-	-	-	-		-	-	-	-	-

Note. Visit was effects coded, personal concern = 1, problem discussion = -1. AR(1) = first-order autoregressive. Only p-values < .10 shown. N = 33 couples.

**Table 3**  
 Parameter estimates predicting change in skin barrier recovery from attachment, controlling for control site TEWL

Parameters	Women				Men				Gender difference		
	Estimate	SE	df	t	p	Estimate	SE	df	t	p	p
Fixed effects											
Intercept, $\gamma_{000}$	0.008	0.02	259	0.42	-	0.02	0.02	255	0.75	-	-
Control site TEWL, $\gamma_{010}$	-0.12	0.01	376	-12.11	<.0001	-0.09	0.01	376	-7.20	<.0001	.04
Time, $\gamma_{100}$	0.52	0.04	278	14.07	<.0001	.046	0.04	303	12.30	<.0001	-
Anxiety, $\gamma_{101}$	0.11	0.03	280	3.47	.0006	-0.10	0.05	310	-2.08	.04	.0003
Avoidance, $\gamma_{102}$	-0.08	0.04	288	-2.22	.03	0.06	0.05	352	1.27	-	.02
Time <sup>2</sup> , $\gamma_{200}$	-0.15	0.02	355	-9.19	<.0001	-0.13	0.02	348	-7.41	<.0001	-
Anxiety, $\gamma_{201}$	-0.05	0.01	367	-3.24	.001	0.05	0.02	352	2.23	.03	.0003
Avoidance, $\gamma_{202}$	0.03	0.02	370	1.65	.10	-0.03	0.02	346	-1.20	-	.05
Effects of visit											
Time, $\gamma_{110}$	0.02	0.03	382	0.51	-	0.03	0.03	378	0.97	-	-
Anxiety, $\gamma_{111}$	-0.02	0.03	380	-0.62	-	-0.12	0.05	376	-2.64	.009	.06
Avoidance, $\gamma_{112}$	0.0003	0.03	380	0.08	-	0.00098	0.04	382	0.02	-	-
Time <sup>2</sup> , $\gamma_{210}$	-0.009	0.02	373	-0.60	-	-0.01	0.02	352	-0.63	-	-
Anxiety, $\gamma_{211}$	0.02	0.01	368	1.44	-	0.04	0.02	353	1.83	.07	-
Avoidance, $\gamma_{212}$	-0.006	0.02	371	-0.36	-	0.002	0.02	347	0.08	-	-
Variances/Covariances	Estimate	SE	z	p	Estimate	SE	z	p			
Time	0.006	0.002	2.68	.004	0.004	0.002	2.51	.006			
Between partners covariance	-0.04	0.27	-0.14	-	-						
AR(1) covariance	0.44	0.05	9.20	<.0001	-						
Within-subject variance, $\epsilon_{ij}$	0.03	0.002	11.12	<.0001	-						

Note. Visit was effects coded, personal concern = 1, problem discussion = -1. AR(1) = first-order autoregressive. Only p-values < .10 shown. N = 33 couples.