Adaptive Human Behavior and Physiology (2015) 1:41–53
DOI 10.1007/s40750-014-0007-z

ORIGINAL ARTICLE

Early Stage Romantic Love is Associated with Reduced Daily Cortisol Production

Omri Weisman · Inna Schneiderman · Orna Zagoory-Sharon · Ruth Feldman

Received: 7 June 2014 / Revised: 20 August 2014 / Accepted: 21 August 2014 / Published online: 6 September 2014

Abstract Early-stage romantic love constitutes a unique phase associated with distinct brain activations and neuro-hormonal processes that function to consolidate the affiliative bond. Little research addressed functioning of the hypothalamic-pituitary-adrenal (HPA) axis during this phase or tested the relationship between cortisol and interactive behavior in new lovers. The current study examined daily cortisol production in 113 healthy young adults, including 79 new lovers who began a romantic relationship within the past 3 months and 34 demographically-matched singles. Saliva samples were collected three times per day on two consecutive days: at awakening, 30 minutes post-awakening, and at bedtime. Couples were videotaped during naturalistic interactions and self-reported on their relationship quality. Basal cortisol, total daily cortisol (AUCg), and cortisol awakening response (CAR) were assessed. New lovers exhibited lower daily cortisol production and blunted CAR, suggesting that the initiation of a romantic bond attenuates the stress response. Observed social reciprocity and goal-directed partnership and reported commitment to the relationship were associated with lower daily cortisol. Findings are consistent with research on the effects of intimate partner relationships on the stress response and support our *bio behavioral synchrony* model by demonstrating links between neuroendocrine processes and reciprocal social behavior during periods of bond formation in humans.

Keywords Cortisol · Romantic attachment · Love · HPA axis · Behavior · Commitment

Introduction

Social bonds are critical for survival and adaptation and periods of bond formation are marked by distinct neurobiological processes, including re-organization of brain networks, up- or down-regulation of endocrine processes, and the emergence of dyad-

O. Weisman · I. Schneiderman · O. Zagoory-Sharon · R. Feldman (✉)
Department of Psychology and the Gonda Brain Sciences Center, Bar-Ilan University, Ramat-Gan 52900, Israel
e-mail: feldman.ruth@gmail.com

specific behavioral patterns (Acevedo et al. 2011; Carter 2014; Emanuele et al. 2006; Feldman 2012a; Insel and Young 2001; Marazziti and Canale 2004 Weisman et al. 2012). Although much research addressed the formation of parent-infant bonding in humans and other mammals, significantly less attention has been directed to pair-bond formation and few studies examined the neurobiology of romantic attachment (de Boer et al. 2012). To date, surprisingly little is known on the biological processes that accompany the stage of “falling in love”, celebrated in literature and the arts as among the peaks of human experience. In this study, we focused on a narrow time-window during the period of pair-bond formation in humans - between 2 weeks and 4 months following the initiation of a romantic relationship - to measure hormonal processes occurring at the early stages of romantic attachment.

The formation of a new romantic relationship is associated with alterations to the stress response at both the behavioral and biological levels. Early-stage romantic love is typically accompanied by intense preoccupations and worries regarding the partner and the relationship, obsessive-like anticipation, focus on minute non-verbal signals, and fears of rejection (Emanuele 2009; Leckman and Mayes 1999; Schneiderman et al. 2014), indicating increased stress. On the other hand, entering a romantic relationship necessitates sufficient calm to mobilize a trusting orientation and an “approach” behavioral repertoire. This unique state of arousal, termed by Carter and Porges (2011) as “immobility without fear”, is critical for the formation of pair bonds and involves attenuation of the stress response. Possibly, distinct biomarkers of the stress response index each of these processes.

Cortisol (CT), a steroid hormone secreted by the HPA axis in response to stress and presenting distinct diurnal rhythms, has been repeatedly associated with psychological, physiological, and physical health. Studies have pointed to the effects of social stress on CT production in humans (Dickerson and Kemeny 2004) and CT has been implicated in the regulation of parenting behaviors in women and men (Fleming et al. 1997; Gordon et al. 2010; Wynne-Edwards 2001; Ziegler 2000). Several studies addressed the involvement of CT in romantic attachment and reported mixed results. Laurent and Powers (2007) found that the HPA system is activated during the early stages of romantic attachment and Marazziti and Canale (2004) showed higher plasma cortisol levels in new lovers during the first 6 months of a romantic relationship as compared to a control group composed of singles and individuals in long-term relationships. Women in a romantic relationships exhibited an increase in circulating CT after merely thinking about their partners (Loving et al. 2009). These findings are consistent animal research, which demonstrated that glucocorticoids promote partner preference (DeVries et al. 1996), probably by enhancing reward from social interaction (Haney et al. 1995). Importantly, these studies mainly relied on a single plasma cortisol assessment or cortisol response to momentary stressors.

In contrast, several studies reported that romantic relationships function to attenuate the stress response. Men and women in a romantic relationship, especially couples in long-term relationships, exhibited lower cortisol levels than singles (Maestripieri et al. 2013). This is consistent with the widely accepted view that long-term intimate relationships reduce anxiety and suppress HPA-axis activity (Esch and Stefano 2005a, 2005b), hence their importance as mediators of the effects of stress on health. In particular, lower cortisol levels were found in couples reporting positive relationships. Correlations were found between lower cortisol and self-reported measures of marital quality (Holt-Lunstad et al. 2008; Saxbe et al. 2008). Women's positive experiences in the marriage, including marital satisfaction and partner disclosure, was found to buffer the effects of work-related stress on cortisol levels (Slatcher et al. 2010). With regards to diurnal cortisol, couples reporting higher levels of intimacy showed decreased daily cortisol production (Ditzen et al. 2008). Since diurnal CT patterns have been repeatedly shown as unrelated to other measures of cortisol, such as baseline plasma levels and momentary stress response (Golden et al. 2013), it is possible that the two measurements tap different aspects of HPA functioning during the early stages of romantic attachment, and that diurnal CT patterns may provide the calm background to enable the formation of the romantic bond.

Cortisol levels have been associated with interactive behavior between attachment partners. Parent-infant interactions marked by sensitivity and reciprocity were related to lower cortisol response to stress and reduced diurnal cortisol production (Feldman et al. 2010; Feldman 2012b; Gordon et al. 2010; Haley and Stansbury 2003). Among romantic couples, partners who displayed greater hostility during conflict interactions showed higher plasma cortisol and greater salivary cortisol response (Schneiderman et al. 2014; Laurent et al. 2013). These findings accord with research demonstrating links between emphatic communication and low CT (Torner et al., 2001), and between interpersonal hostility and elevated CT levels (Burke et al. 2005). The findings are also consistent with the hypothesis that the benefits of positive social relationships, particularly empathic couple relationships, are mediated to some degree by their effects on reducing HPA reactivity (Ditzen et al. 2007; Robles and Kiecolt-Glaser, 2003).

One possible reason for the inconsistent findings on the effects of romantic attachment on HPA functioning may relate to variations in CT measurement; plasma versus saliva and reactive cortisol versus diurnal patterns. In the current study, we chose to examine daily cortisol production. Two aspects of daily cortisol rhythms– *total daily cortisol production*, and *cortisol awakening response* (CAR, Pruessner et al. 1997) – may be of particular interest given their sensitivity to attachment- and health-related processes. For example, elevated levels of daily cortisol and CAR independently predicted poor health outcomes (Adam and Kumari 2009). Dysfunctional parenting, including emotional maltreatment, inadequate parental care, parental loss, and disturbed family relationships have similarly been linked with greater daily cortisol production and higher CAR (Gunnar and Quevedo 2007). We thus hypothesized that diurnal cortisol may provide the background state of calm that enables the initiation of a romantic relationship and that early-stage romantic love would be associated with attenuated daily cortisol production and blunted CAR.

In addition, we measured associations between daily cortisol and CAR and the couple's observed social reciprocity and joint partnership during naturalistic interactions. The degree of social engagement, mutuality, and reciprocity between new couples may have a special role in attenuating the stress response in light of the known effects of positive couple relationships on HPA suppression (Ditzen et al. 2007; Meuwly et al. 2012; Laurent et al. 2013). In addition to observed behavior, we measured the three components of Sternberg's Triangular Theory of Love (Sternberg 1986)– passion, intimacy, and commitment – in relation to total cortisol production and CAR. According to this theory, love relationships can be characterized as more passionate, dynamic, highly-arousing, and unpredictable or as more committed, secure, intimate, and stable.

Males with a narcissistic personality, who are typically characterized by lower relationship commitment and greater need for high arousal, were shown to exhibit higher basal cortisol levels (Reinhard et al. 2012), suggesting that low commitment and greater arousal may be associated with higher CT. We thus examined whether the dimension of passionate love may correlate with greater unpredictability and stress and higher cortisol secretion whereas intimacy and commitment, indicative of stability and safety, may be associated with lower cortisol production and attenuated CAR.

Methods

Participants

One hundred and 55 young adults participated in two groups. The "new couples" group included 120 young non-cohabitating heterosexual adults (60 couples, with equal representation for men and women) who began their romantic relationship on average 2.4 months prior to their entry into the study (relationship duration ranged between 2 weeks and 4 months; mean age=23.93, *SD*=6.6). Couples were not screened or included in the study on the basis of their passionate love levels, and their average score on the "passion" sub-scale of Sternberg's Triangualr Love Scale was 107 which reflects "somewhat above average" level (Sternberg 1997). In the current sample, relationships were characterized by "intimacy" and "commitment" to the same extent as by "passion" (score of 116 for both intimacy and commitment, indicating "somewhat above average" levels).

The "singles" group was intentionally smaller and included 35 young adults (21 women) who were not involved in any kind of romantic relationship and did not separate from a former romantic partner within the past 3 months (mean age=22.3, *SD*=2.3). The female bias in the smaller sample was caused by recruitment constraints, and should be considered a study limitation. All participants were of middle-class background and most were students. Exclusion criteria for the entire sample included individuals who did not complete high school education, were above 35 years, or reported taking medication or not being generally healthy. Of these, 79 new lovers and 34 singles gave three saliva samples on two consecutive days.

Procedure

Participants were instructed to collect saliva samples at awakening, 30 minutes post-awakening, and just before bedtime on two consecutive weekend days. Saliva was collected by passively drooling into a labeled plastic tube. Prior to the collection of each sample, participants had to adhere to guidelines of nil by mouth other than water and the avoidance of vigorous exercise and brushing teeth. Other than these requests participants were free to follow their normal routine. Samples were stored in the participants' home freezers on the same day of collection. Insulated packs were used to transfer samples to the laboratory where they were stored at -20^{c} until assay. On each study day participants recorded their awakening time and the exact times of saliva sampling. All participants reported collecting the first sample immediately or within minutes after awakening. Saliva collection was taken place following the couples' visit to the lab (detailed below).

Couples, but not singles, were also asked to arrive at the lab for a videotaped interaction that included two paradigms; positive and support giving. In the positive episode, couples were instructed to discuss a shared positive experience for approximately 7 minutes. In the support-giving episode, partners were instructed to describe to each other a situation that caused them personal distress but was not related to the romantic relationship (e.g., work or family problems) and take turns for approximately 7 min each. Order of speaker–listener was decided by the couple. Interactive sessions were held prior to cortisol sampling, which took place during the subsequent weekend or the one thereafter, and were always separated by several days to avoid carryover effect of the sessions on the participants' cortisol levels.

Cortisol Assay

Saliva samples underwent several freeze-thaws cycles and vortex in order to precipitate the mucus. After the forth cycle the tubes were centrifuge at 1,500 g (at 3,000 rpm) for 20 min. Supernatants were collected and stored again at -20^{c} until assayed. Cortisol determination was performed using a commercial ELISA kit (Enzo Life Sciences, USA). On the day of the assay samples were thawed and 100 μL was pipette into appropriate well. Measurement was performed in duplicates and the concentration of samples was calculated using MatLab-7 (MathWorks, USA) according to the kit's standard curves. The intra-assay and inter-assay coefficients were 10.12 and 31.1 %, respectively.

Behavioral Coding

Interactions were coded using the adult version of the Coding Interactive Behavior (CIB; Feldman 1998) system. Coding was conducted by trained coders who were blind to any information about the participants. The CIB has good psychometric properties and has shown sensitivity to differences related to age, interactive partner, cultural background, and risk conditions and has been validated in multiple studies of children and adults (for summary of psychometric measures, see Feldman 2012b). The adult–adult version of the CIB included 33 scales: 28 are identical scales that are coded independently for each partner (e.g. attention to partner) and five scales are coded for the couple as a whole and address dyadic measures. Each scale is rated on a Likert scale of 1=low to 5=high. The adult-adult version of the CIB has been validated in several studies (Schneiderman et al. 2012, 2014). Based on existing literature, two behavioral constructs were computed: *Goal-oriented partnership* was computed as the average of the following scales: on-task persistence in discussing the positive experience, visual attention to partner, and consistency of style. *Social Reciprocity* was the average of the following codes; positive affect, matched dyadic states, and dyadic reciprocity. Inter-rater reliability, conducted for 15 % of the sample, averaged, showed intraclass r=.94 (range=.88−.99).

Cortisol Analysis

Cortisol values were found to have substantial skew and were therefore log-transformed (to base 10) prior to analysis. Two components of cortisol were computed: the area under the curve with respect to ground (AUCg; Pruessner et al. 2003), and CAR. The AUCg was used as a measure of total cortisol secretion (in pg\mL) during each day - from awakening until bedtime. To correct for differences in length of total sampling interval time, the AUCg was divided by number of hours between the first and the last cortisol sample. The AUCg was computed for 34 singles and 79 in-relationship subjects that had at least three saliva samples in one of the days. The CAR was calculated as the difference between the cortisol value at awakening and the value 30 min after awakening. Among the 41 individuals that were withdrawn from analysis, 32 (15 females) did not return any sample back to the experimenter. Additional nine subjects returned samples, but those were either lacking sufficient saliva for ELISA analysis or too many samples were missing.

Self-Report

The Triangular Love Scale (TLS) consists of 45 items assessing the following three dimensions of romantic love (15 items each): *intimacy*, *passion*, and *commitment* to one's partner (Sternberg 1997). Respondents were asked to think about the relationship with their partner and rate each item on a 9-point scale.

Statistical Analysis

Multivariate Analysis Of Variance (MANOVA) was calculated with group (lovers, singles) and gender as the between-subject factors and average CAR and AUCg levels of both days as the dependent variables. Next, repeated-measures ANOVA with group and gender as between-subject factors and time (awakening, +30 min, bedtime) as within-subject factor examined change in daily cortisol secretion. Following, independent *t*-test was used for to measure group differences in AUCg. Pearson correlations were conducted to examine potential associations between couples' interactive behavior, self-report measures, and cortisol variables. Finally, Pearson correlations between cortisol levels at each of time point (in two consecutive days) are reported for the entire sample.

Results

a. Cortisol Secretion in Couples and Singles

   Multivariate analysis revealed a main effect for group, F (2,86)=7.09, p=.001, Eta^2=.14, with singles showing greater overall daily cortisol secretion and CAR as compared to new couples. No gender or group by gender effects were found.

   Repeated-measure analysis of the three cortisol samples showed a substantial main effect for time, F (1,82)=182.81, p=.009, Eta^2=.68, indicating that cortisol levels markedly changed across the day. The AUCg score was higher in singles than new lovers, t (111)=2.32, p=.022 (Fig. 1a,b). When testing for CAR, significant main effect for group emerged, F (1,87)=6.26, p=.01, Eta^2=.07, with singles exhibiting higher CAR (Fig. 1c). This effect remained significant when controlling for baseline cortisol, F (1,88)=9.24, p=.003, Eta^2=.09, confirming to the robustness of the group effect. No gender effect or gender by group interaction was found. Basal cortisol did not differentiate between groups.

b. Couples' Interactive Behaviors and Daily Cortisol Secretion

   Couples exhibiting low daily cortisol (median split of AUCg) showed significantly more *goal-directed partnership*, *t* (68)=2.97, *p*=.004, and, *reciprocity*, *t* (68)=3.70, *p*=.000, during interactions as compared to individuals with high levels of daily cortisol (Fig. 2a, b). Daily cortisol was negatively associated with *goal-directed partnership*, *r*=−.30, *p*=.01, and *reciprocity*, *r*=−.32, *p*=.006.

c. Self-Reports of Love and Couples' Cortisol Secretion

Participants' reports of "being in-love" was higher among those with low versus high daily cortisol, *t* (74)=3.72, *p*=.001 (Fig. 2c), and daily cortisol and level of "being in-love" was negatively correlated, *r*=−.26, *p*=.025. CAR was unrelated to rating of "being-in-love", but "being-in-love" was negatively correlated with basal cortisol, *r*=−.25, *p*=.04.

Participants with low daily cortisol scored higher on the "commitment love" subscale of the TLS, compared to individuals with high daily cortisol, *t* (74)=2.24, *p*=.03. No differences in "passionate" or "intimacy" scores were related to cortisol measures.

d. Inter-Correlations between Cortisol Samples

Table 1 details the correlations between cortisol levels for the entire sample. Results show high individual stability within a day as well as between two consecutive days. Given that cortisol values were within the normal range, these high correlations provide further validation for the data. Finally, we examined whether CT production was related to length of the romantic relationship and found no association between the duration of the couple's relationship with any cortisol measure.

Discussion

Results of the current study – the first to examine daily cortisol production in romantic partners during the first 3 months of falling in love in relation to interactive behavior –

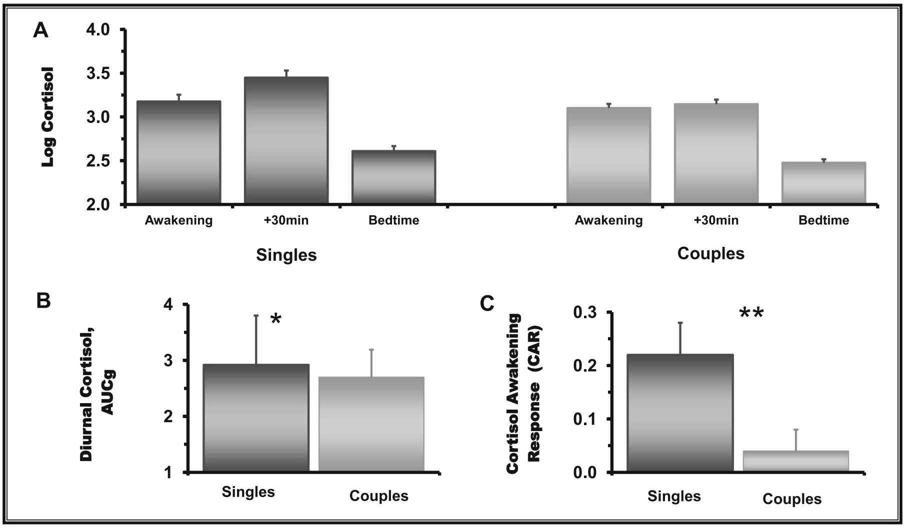

Fig. 1 Comparing singles' versus couples' (**a**) cortisol levels at three time points along the day; (**b**) total daily cortisol secretion (*AUCg*); and, (**c**) cortisol awakening response (*CAR*). Bottom of the figure: * $p<.05$, ** $p=.01$

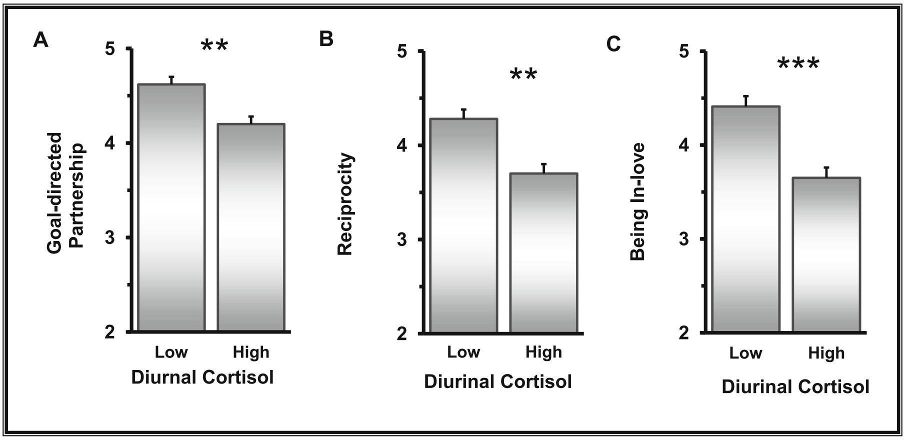

Fig. 2 Daily cortisol (*log AUCg*) and couples' dyadic behaviors and, level of "being in-love". Bottom of the figure: ** $p<.01$, *** $p<.001$

indicate that early stage romantic love is associated with attenuated cortisol as indexed by reduced daily CT production and blunted CAR. Both reduced CT levels and lower CAR were associated with greater social reciprocity and partnership between new lovers and reported commitment to the relationship. This suggests that one mechanism by which new romantic relationships affect the stress response is via reciprocal and synchronous relational behavior within a committed affiliative bond. Such findings accord with our conceptual model on *bio behavioral synchrony* (Feldman 2007, 2012a, 2012b, 2014), which demonstrates the pervasive and long-term effects of matched social behavior within attachment relationships on brain response, immune system, hormonal processes, and autonomic functioning, as well as on the individual's well-being, emotion regulation, and social competence.

In general, positive social relationships in humans have been associated with a host of health-related outcomes, including reduced cardiovascular risk and mortality, greater subjective well-being, and better neuroendocrine regulation (Cohen and Wills 1985; Ryff et al. 2004). In contrast, social isolation, indifference, and rejection within close

Table 1 Pearson correlations among within-day and between-days cortisol assessments

Day 1			Day 2		
Awake	+30 min	Bedtime	Awake	+30 min	Bedtime
Day 1: Awake	.64***	.28***	.50***	.40***	.42***
+30 min	–	.33***	.476***	.50	.39***
Bedtime	–	–	.17	.27**	.15
Day 2: Awake	–	–	–	.38***	.28**
+30 min	–	–	–	–	.15
Bedtime	–	–	–	–	–

**$p\leq.01$, ***$p\leq.001$

Note: correlations include men and women of both new lovers and singles groups relationships are related to greater propensity for psychopathology (Enns et al. 2002) and increased cardiovascular, endocrine, and immune problems (Uchino et al. 1996). Research has also shown that the degree of empathy between couples affects the functioning of multiple physiological and hormonal systems, including sympathetic arousal, oxytocin response, prolactin, and testosterone (Mosek-Eilon et al. 2013; Schneiderman et al. 2014). It has been suggested that one pathway by which long-term relationships enhance health and well-being is via their effect on modulating the HPA stress response, which, in turn, improves sleep patterns and immune functioning and reduces the prevalence of metabolic dysfunction, cardiovascular diseases, and mortality (Loving and Slatcher 2013).

Our findings accord with studies demonstrating the effects of satisfying marital relationships on reducing HPA response (Ditzen et al. 2008; Slatcher et al. 2010). Yet, in the main, this body of research did not examine HPA response as a function of relationship duration and it is not possible to ascertain at what stage positive partnerships affect the stress response. In one study, Maestripieri et al. (2013) found that singles exhibited the highest cortisol response, individuals in short-term relationships showed mid-levels, and those in long-term positive relationships had lowest cortisol levels, suggesting incremental effect with relationship duration. By carefully selecting a time-window of 2 weeks to 4 months after the initiation of a romantic bond, our findings can demonstrate that already at this early phase of relationship formation, romantic attachment exerts positive effects on HPA functioning. The fact that no cortisol measurement correlated with relationship duration within this time-window but both total daily production and the CAR were associated with social reciprocity, goal directed partnership, and relationship commitment suggests that it is the sense of mutuality and security in the relationship that buttress the effect of romantic attachment on the stress response, and that this effect can be observed already 2–3 weeks after the beginning of the relationship. These findings are consistent with studies indicating that neurobiological processes during the period of falling in love are intense, rapid, and quickly reorganize brain, hormones, and behavior (Fisher et al. 2005, 2006, 2002; Schneiderman et al. 2012, 2014).

While ours is the first study, to our knowledge, to examine daily cortisol production in new lovers during the first months of a romantic relationship in comparison with singles, the mixed results in the literature should be considered. For instance, Marazziti and Canale (2004) found higher baseline plasma cortisol in a group of new lovers in the first 6 months of their relationship as compared to a control group including both singles and individuals in long-term relationships. Similarly, Loving et al. (2009) reported higher salivary cortisol reactivity in women when asked to think of their loved ones. Two reasons may account for the divergent findings. Apart from methodological issues of combining singles and individuals in long-term relationship as controls for new lovers, which – according to Maestripieri et al. (2013) represent opposite ends of the cortisol response with new lovers in the middle - this study included a single plasma measurement of CT. Similarly, Loving et al. (2009) study tested cortisol response, not diurnal patterns. Possibly, the intense stage of romantic bond-formation affects the two aspects of HPA functioning in different ways. It sharpens HPA response to momentary stressors, particularly in tasks related to the attachment bond, such as thinking of partner or conflict discussion, and at the same time it provides a soothing buffer to the involuntary daily functioning of the system, expressed in diurnal patterns. As such, early romantic attachment may both increase acute response to stress-related signals associated with the affiliative bond while providing a backdrop of calm for the initiation of approach behavior. This argument is supported by the consistent findings that diurnal, plasma, and reactive cortisol measurements are unrelated (Golden et al. 2013). Another possible explanation relates to the specific dimensions of the relationship tested in the different studies. Our participants were not selected on the basis of passionate love, as the Marazziti and Canale (2004) study, and reported comparable levels of "commitment" and "passion" toward their partners. Furthermore, the degree of commitment, not passion, correlated with cortisol production. It is possible that the element associated with alteration in cortisol is not the highly arousing aspect of passion but the aspect of commitment, and the sense of security individuals experience within close relationship is the mechanism that triggers the calming effect.

Our study is also the first to examine daily cortisol production in relation to observed social interaction between new lovers. We found that romantic couples exhibiting greater social reciprocity and goal-directed partnership, including the expression of positive affect, matched dyadic states, visual attention to partner, consistent and predictable style, and focus on listening to the partner and jointly accomplishing the task at hand, had lower daily cortisol production and attenuated CAR. These findings echo research of the parent-infant relationship which indicated that reciprocity, synchrony, and partnership in the mother-child and father-child relationship were associated with reduced cortisol response as indexed by lower plasma CT, reduced diurnal cortisol, and lower salivary cortisol response to momentary stressors linked with attachment relationship (e.g., the still-face effect) (Feldman et al. 2007, 2009, 2010; Gordon et al. 2010). These findings are consistent with our conceptualization (Feldman et al. 2012a) that parallel biological processes underpin parental and romantic attachment, that the two types of affilative bonds are expressed in similar forms of social behavior, and that in both attachments the effects of the relationship on biological processes is mediated by the partners' interactive behaviors during moments of social contact.

Several limitations of the study should be considered in the interpretation of the findings. First, we did not measure the amount of time couples spent together during the weekend of saliva collection and this could have affected individual variability in cortisol production. Second, assessing cortisol across several weekends or through measures that reflect long-term stress, such as hair cortisol, could have provided a more in-depth assessment of HPA-system functioning across the period of pair bond formation (Stalder and Kirschbaum 2012; Russell et al. 2012). Including more cortisol assessment points during the day would have provided better assessment of diurnal rhythms, and the higher number of females in the singles groups is a clear study limitation. In addition, there may be a number of differences that account for the interaction between cortisol and relationship status, including sleeping patterns, sexual arousal, and ruminative thoughts and these were not assessed in the current study.

Future research is required to specify the long-term effects of variability in couples' interaction patterns on HPA system functioning and address how the attenuated stress response, in turn, functions to consolidate the relationship and confer health-related benefits. Despite the fact that the HPA-axis is an important player in the process of bond formation, it is only one system interacting within a complex neurohormonal milieu and its associations with other hormones and physiological systems should be tested. Much further research is required to understand how selective and enduring affiliative bonds function to shape brain and behavior, improve well-being and health, and provide a sense of security and calm, purpose and meaning.

Acknowledgments Supported by the German-Israeli Foundation (#1114-101.4/2010), the US-Israel Bi-National Foundation (#2011349), and I-CORE Program of the Planning and Budgeting Committee and The Israel Science Foundation (grant No. 51/11)".

References

Acevedo, B. P., Aron, A., Fisher, H. E., & Brown, L. L. (2011). Neural correlates of long-term intense romantic love. *Social Cognitive and Affective Neuroscience, 7*(2), 145–159.
Adam, E. K., & Kumari, M. (2009). Assessing salivary cortisol in large-scale, epidemiological research. *Psychoneuroendocrinology, 34*, 1423–1436.
Burke, H. M., Davis, M. C., Otte, C., & Mohr, D. C. (2005). Depression and cortisol responses to psychological stress: a meta-analysis. *Psychoneuroendocrinology, 30*(9), 846–856.
Carter, C. (2014). Oxytocin Pathways and the Evolution of Human Behavior. *Annual Review of Psychology, 65*(1).
Carter, C. S., & Porges, S. W. (2011). *The neurobiology of social bonding and attachment. The Oxford handbook of social neuroscience* (pp. 151–163). New York: Oxford University Press.
Cohen, S., & Wills, T. A. (1985). Stress, social support, and the buffering hypothesis. *Psychological Bulletin, 98*(2), 310–57.
de Boer, A., van Buel, E. M., & Ter Horst, G. J. (2012). Love is more than just a kiss: a neurobiological perspective on love and affection. *Neuroscience, 201*, 114–24.
DeVries, A. C., DeVries, M. B., Taymans, S. E., & Carter, C. S. (1996). The effects of stress on social preferences are sexually dimorphic in prairie voles. *Proceedings of the National Academy of Sciences, 93*(21), 11980–11984.
Dickerson, S. S., & Kemeny, M. E. (2004). Acute stressors and cortisol responses: a theoretical integration and synthesis of laboratory research. *Psychological Bulletin, 130*(3), 355.
Ditzen, B., Neumann, I. D., Bodenmann, G., von Dawans, B., Turner, R. A., Ehlert, U., & Heinrichs, M. (2007). Effects of different kinds of couple interaction on cortisol and heart rate responses to stress in women. *Psychoneuroendocrinology, 32*, 565–574.
Ditzen, B., Hoppmann, C., & Klumb, P. (2008). Positive couple interactions and daily cortisol: on the stress-protecting role of intimacy. *Psychosomatic Medicine, 70*(8), 883–889.
Emanuele, E. (2009). Of love and death: the emerging role of romantic disruption in suicidal behavior. *Suicide and Life-Threatening Behavior, 39*(2), 240–240.
Emanuele, E., Politi, P., Bianchi, M., Minoretti, P., Bertona, M., & Geroldi, D. (2006). Raised plasma nerve growth factor levels associated with early-stage romantic love. *Psychoneuroendocrinology, 31*(3), 288–294.
Enns, M. W1., Cox, B. J., & Clara, I. (2002). Parental bonding and adult psychopathology: results from the US national comorbidity survey. *Psychological Medicine, 32*(6), 997–1008.
Esch, T., & Stefano, G. B. (2005a). Love promotes health. *Neuro Endocrinology Letters, 26*, 264–267.
Esch, T., & Stefano, G. B. (2005b). The neurobiology of love. *Neuro Endocrinology Letters, 26*, 175–192.
Feldman, R. (1998). Coding interactive behavior manual. Unpublished manual.
Feldman, R. (2007). Parent-infant synchrony and the construction of shared timing; physiological precursors, developmental outcomes, and risk conditions. *Journal of Child Psychology and Psychiatry, 48*(3–4), 329–54.
Feldman, R. (2012a). Oxytocin and social affiliation in humans. *Hormones and Behavior, 61*, 380–391.
Feldman, R. (2012b). Parenting behavior as the environment where children grow. In L. C. Mayes & M. Lewis (Eds.), *The Cambridge handbook of environment in human development* (pp. 535–567). New York: Cambridge University Press.
Feldman, R. (2014). Sensitive periods in social development: New insights from research on oxytocin, synchrony, and high-risk parenting. *Development and Psychopathology.*

Feldman, R., Weller, A., Zagoory-Sharon, O., & Levine, A. (2007). Evidence for a neuroendocrinological foundation of human affiliation: plasma oxytocin levels across pregnancy and the postpartum period predict mother-infant bonding. *Psychological Science, 18*(11), 965–70.

Feldman, R., Granat, A., Pariente, C., Kanety, H., Kuint, J., & Gilboa-Schechtman, E. (2009). Maternal depression and anxiety across the postpartum year and infant social engagement, fear regulation, and stress reactivity. *Journal of the American Academy of Child and Adolescent Psychiatry, 48*(9), 919–27. doi:10.1097/CHI.0b013e3181b21651.

Feldman, R., Singer, M., & Zagoory, O. (2010). Touch attenuates infants' physiological reactivity to stress. *Developmental Science, 13*(2), 271–8. doi:10.1111/j.1467-7687.2009.00890.x.

Feldman, R., Bamberger, E., & Kanat-Maymon, Y. (2013). Parent-specific reciprocity from infancy to adolescence shapes children's social competence and dialogical skills. *Attachment & Human Development, 15*(4), 407–423.

Fisher, H. E., Aron, A., Mashek, D., Li, H., & Brown, L. L. (2002). Defining the brain systems of lust, romantic attraction, and attachment. *Archives of Sexual Behavior, 31*(5), 413–419.

Fisher, H., Aron, A., & Brown, L. L. (2005). Romantic love: an fMRI study of a neural mechanism for mate choice. *Journal of Comparative Neurology, 493*(1), 58–62.

Fisher, H. E., Aron, A., & Brown, L. L. (2006). Romantic love: a mammalian brain system for mate choice. *Philosophical Transactions of the Royal Society, B: Biological Sciences, 361*(1476), 2173–2186.

Fleming, A. S., Ruble, D., Krieger, H., & Wong, P. Y. (1997). Hormonal and experiential correlates of maternal responsiveness during pregnancy and the puerperium in human mothers. *Hormones and Behavior, 31*(2), 145–158.

Golden, S. H., Sánchez, B. N., Wu, M., Champaneri, S., Diez Roux, A. V., Seeman, T., & Wand, G. S. (2013). Relationship between the cortisol awakening response and other features of the daily cortisol rhythm: the multi-ethnic study of atherosclerosis. *Psychoneuroendocrinology, 38*(11), 2720–2728.

Gordon, I., Zagoory-Sharon, O., Leckman, J. F., & Feldman, R. (2010). Oxytocin, cortisol, and triadic family interactions. *Physiology and Behavior, 101*, 679–684.

Gunnar, M., & Quevedo, K. (2007). The neurobiology of stress and development. *Annual Review of Psychology, 58*, 145–173.

Haley, D. W., & Stansbury, K. (2003). Infant stress and parent responsiveness: regulation of physiology and behavior during still-face and reunion. *Child Development, 74*(5), 1534–1546.

Haney, M., Maccari, S., Le Moal, M., Simon, H., & Vincenzo Piazza, P. (1995). Social stress increases the acquisition of cocaine self-administration in male and female rats. *Brain Research, 698*(1), 46–52.

Holt-Lunstad, J., Birmingham, W. A., & Light, K. C. (2008). Influence of a "warm touch" support enhancement intervention among married couples on ambulatory blood pressure, oxytocin, alpha amylase, and cortisol. *Psychosomatic Medicine, 70*, 976–985.

Insel, T. R., & Young, L. J. (2001). The neurobiology of attachment. *Nature Review Neuroscience, 2*(2), 129–36.

Laurent, H., & Powers, S. (2007). Emotion regulation in emerging adult couples: temperament, attachment, and HPA response to conflict. *Biological Psychology, 76*(1–2), 61–71.

Laurent, H. K., Powers, S. I., Laws, H., Gunlicks-Stoessel, M., Bent, E., & Balaban, S. (2013). HPA regulation and dating couples' behaviors during conflict: gender-specific associations and cross-partner interactions. *Physiology & Behavior, 118*, 218–226.

Leckman, J. F., & Mayes, L. C. (1999). Preoccupations and behaviors associated with romantic and parental love. Perspectives on the origin of obsessive-compulsive disorder. *Child and Adolescent Psychiatric Clinics of North America, 8*(3), 635–665.

Loving, T. J. & Slatcher, R.B. (2013). Romantic relationships and health. In J. Simpson & L.Campbell (Eds.), The Oxford Handbook of Close Relationships (pp. 617–637). Oxford: New York.

Loving, T. J., Crockett, E. E., & Paxson, A. A. (2009). Passionate love and relationship thinkers: experimental evidence for acute cortisol elevations in women. *Psychoneuroendocrinology, 34*(6), 939–946.

Maestripieri, D., Klimczuk, A. C., Seneczko, M., Traficonte, D. M., & Wilson, M. C. (2013). Relationship status and relationship instability, but not dominance, predict individual differences in baseline cortisol levels. *PloS One, 8*(12), e84003.

Marazziti, D., & Canale, D. (2004). Hormonal changes when falling in love. *Psychoneuroendocrinology, 29*, 931–936.

Meuwly, N., Bodenmann, G., Germann, J., Bradbury, T. N., Ditzen, B., & Heinrichs, M. (2012). Dyadic coping, insecure attachment, and cortisol stress recovery following experimentally induced stress. *Journal of Family Psychology, 26*(6), 937.

Mosek-Eilon, V., Hirschberger, G., Kanat-Maymon, Y., & Feldman, R. (2013). Infant reminders alter sympathetic reactivity and reduce couple hostility at the transition to parenthood. *Developmental Psychology, 49*(7), 1385–95. doi:10.1037/a0030088.
Pruessner, J. C., Wolf, O. T., Hellhammer, D. H., Buske-Kirschbaum, A., von Auer, K., Jobst, S., Kaspers, F., & Kirschbaum, C. (1997). Free cortisol levels after awakening: a reliable biological marker for the assessment of adrenocortical activity. *Life Sciences, 61*(26), 2539–2549.
Pruessner, J. C., Kirschbaum, C., Meinlsmidt, G., & Hellhammer, D. H. (2003). Two formulas for computation of the area under the curve represent measures of total hormone concentration versus timedependent change. *Psychoneuroendocrinology, 28*, 916–931.
Reinhard, D. A., Konrath, S. H., Lopez, W. D., & Cameron, H. G. (2012). Expensive egos: narcissistic males have higher cortisol. *PloS One, 7*(1), e30858.
Robles, T. F., & Kiecolt-Glaser, J. K. (2003). The physiology of marriage: pathways to health. *Physiology and Behavior, 79*(3), 409–16.
Russell, E., Koren, G., Rieder, M., & Van Uum, S. (2012). Hair cortisol as a biological marker of chronic stress: current status, future directions and unanswered questions. *Psychoneuroendocrinology, 37*(5), 589–601.
Ryff, C. D., Singer, B. H., & Dienberg Love, G. (2004). Positive health: connecting well-being with biology. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences, 359*(1449), 1383–94.
Saxbe, D. E., Repetti, R. L., & Nishina, A. (2008). Marital satisfaction, recovery from work, and daily cortisol among men and women. *Health Psychology, 27*(1), 15–25.
Schneiderman, I., Zagoory-Sharon, O., Leckman, J. F., & Feldman, R. (2012). Oxytocin during the initial stages of romantic attachment: relations to couples' interactive reciprocity. *Psychoneuroendocrinology, 37*, 1277–1285.
Schneiderman, I., Kanat-Maymon, Y., Zagoory-Sharon, O. & Feldman, R. (2014). Mutual influences between partners' hormones shape conflict dialog and relationship duration at the initiation of romantic love. Social Neuroscience.
Slatcher, R. B., Robles, T. F., Repetti, R. L., & Fellows, M. D. (2010). Momentary work worries, marital disclosure, and salivary cortisol among parents of young children. *Psychosomatic Medicine, 72*(9), 887–896.
Stalder, T., & Kirschbaum, C. (2012). Analysis of cortisol in hair– State of the art and future directions. *Brain, Behavior, and Immunity, 26*(7), 1019–1029.
Sternberg, R. J. (1986). A triangular theory of love. *Psychological Review, 93*(2), 119.
Sternberg, R. J. (1997). Construct validation of a triangular love scale. *European Journal of Social Psychology, 27*, 313–335.
Uchino, B. N., Cacioppo, J. T., & Kiecolt-Glaser, J. K. (1996). The relationship between social support and physiological processes: a review with emphasis on underlying mechanisms and implications for health. *Psychological Bulletin, 119*(3), 488–531.
Weisman, O., Feldman, R., & Goldstein, A. (2012). Parental and romantic attachment shape brain processing of infant cues. *Biological Psychology, 89*(3), 533–538.
Wynne-Edwards, K. E. (2001). Hormonal changes in mammalian fathers. *Hormones and Behavior, 40*(2), 139–145.
Ziegler, T. E. (2000). Hormones associated with non-maternal infant care: a review of mammalian and avian studies. *Folia Primatologica, 71*(1–2), 6–21.