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For Better or Worse? Coregulation of Couples' Cortisol Levels and Mood States

Darby Saxbe and Rena L. Repetti
University of California, Los Angeles

Although a majority of adults live with a close relationship partner, little is known about whether and how partners' momentary affect and physiology covary, or "coregulate." This study used a dyadic multilevel modeling approach to explore the coregulation of spouses' mood states and cortisol levels in 30 married couples who sampled saliva and reported on mood states 4 times per day for 3 days. For both husbands and wives, own cortisol level was positively associated with partner's cortisol level, even after sampling time was controlled. For wives, marital satisfaction weakened the strength of this effect. Partner's negative mood was positively associated with own negative mood for both husbands and wives. Marital satisfaction fully moderated this effect, reducing the strength of the association between one's own and one's partner's negative mood states. Spouses' positive moods were not correlated. As expected, within-couple coregulation coefficients were stronger when mood and cortisol were sampled in the early morning and evening, when spouses were together at home, than during the workday. The results suggest that spouses' fluctuations in negative mood and cortisol levels are linked over several days and that marital satisfaction may buffer spouses from their partners' negative mood or stress state.

Keywords: dyadic processes, marital satisfaction, hypothalamic-pituitary-adrenal (HPA) axis, emotion transmission, coregulation

Psychology has traditionally focused on the individual as the unit of analysis—but humans exist within relationships and are therefore reactive and responsive to inputs from friends, partners, and children. Social connectedness can affect both mental and physical health; for example, social network size and the perceived availability of social support have been associated with longevity, physical symptoms, and vulnerability to ailments ranging from the common cold to cancer (Uchino, Cacioppo, & Kiecolt-Glaser, 1996). For many adults, marriage constitutes their most central and enduring social relationship and has been linked with greater life satisfaction, lower rates of depression, and a reduced risk of all-cause mortality. At the same time, poor marital quality may compromise health, particularly for women (cf. Burman & Margolin, 1992; Gallo, Troxel, Matthews, & Kuller, 2003; Kiecolt-Glaser & Newton, 2001).

Darby Saxbe and Rena L. Repetti, Department of Psychology, University of California, Los Angeles.

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Correspondence concerning this article should be addressed to Darby Saxbe, Department of Psychology, Franz Hall, University of California, Los Angeles, CA 90095. E-mail: dsaxbe@ucla.edu

Despite the established importance of the marital context for individual health, little is known about the interplay of mood and physiology between spouses. Do partners "coregulate," or show synchrony, in their everyday physiological and affective states? When couples vow to stay together "for better or worse," do they also expect to share in each other's momentary ups and downs? Additionally, how is coregulation linked with relationship functioning? Considering that most adults, in the United States and worldwide, cohabit with a spouse or close relationship partner (Kreider, 2005), the question of physiological and emotional coregulation within couples may have wide-ranging health implications.

Defining Coregulation

Attachment researchers have theorized that attunement with a stable, responsive caregiver may facilitate children's regulation of attention, emotion, and physiological arousal. In other words, attachment relationships seem to provide a "homeostatic set point" for children whose self-regulatory abilities are still developing (Sbarra & Hazan, 2008). In both human and animal infants, physical contact with early caregivers helps to organize sleep and eating behavior and the development of autonomic systems like the vagal system, as has been observed in rats (Hofer, 1984) and in human babies who receive "kangaroo care" (skin-to-skin maternal contact; Feldman & Eidelman, 2003).

It is a provocative, although largely untested, notion that adults may also coregulate with close others (Diamond, 2001; Pietromonaco, Barrett, & Powers, 2006; Sbarra & Hazan, 2008). Cohabiting partners may influence each other's moods and physiology; for example, McClintock (1971) has reported that roommates' menstrual cycles become synchronized over time. Other researchers have found evidence of emotional contagion and convergence within adult dyads (e.g., Anderson, Keltner, & John, 2003; Butner, Diamond, & Hicks, 2007). Sbarra and Hazan (2008) have suggested that *coregulation*, defined as the up- or down-regulation of one partner's psychophysiological arousal by the other partner, may be an important feature of adult romantic attachment. This notion of interwoven patterns of physiology and affect within close relationships has been called *synchrony*, *social entrainment*, and *attunement*, but we follow Sbarra and Hazan's (2008) lead in adopting the term *coregulation*, which seems to best capture the phenomenon of dynamic, reciprocal interchange between partners across multiple biological systems. It is important to distinguish between coregulation and stress buffering, or the ability of close relationship partners to dampen the impact of each other's stressful experiences. Whereas stress buffering implies a unipolar direction of effects—that is, toward a reduction in one partner's arousal and negative affect—coregulation suggests that couples' patterns of mood and physiology influence each other bidirectionally. Coregulation may also be distinct from empathy or perspective taking, both because of this bidirectional quality and because coregulation may occur without conscious effort or even awareness.

Since adult coregulation has been little explored, many unanswered questions remain. For example, does coregulation imply greater similarity or greater dissimilarity in partners' psychophysiological states? In the psychotherapy research literature, physiological concordance between clients and clinicians has been linked with ratings of therapist empathy (e.g., Marci, Ham, Moran, & Orr, 2007), suggesting that similarity in somatic arousal may further perceptions of social connectedness. At the same time, marital conflict researchers have found a high degree of physiological linkage between spouses to be a risk factor for relationship distress, through negative affect reciprocity (Gottman, Coan, Carrere, & Swanson, 1998; Levenson & Gottman, 1983), in which partners become trapped in a feedback loop of tension and anger. Partners in happier marriages appear to show more divergent levels of arousal in conflict situations, perhaps because one partner may be attempting to deescalate and calm the more activated spouse. From an attachment perspective, a caregiver who can help to modulate an infant's arousal—for example, by soothing a crying baby—might appear more responsive than is a caregiver who simply mirrors the child's distress. Therefore, effective coregulation may manifest itself through the divergence, or balancing, of partners' affect and arousal rather than through similarity.

An additional question is, what causes coregulation? Is coregulation a by-product of partners' shared environments and experiences, or an outgrowth of social interactions? Or might partners exert direct influences on each other's moods and physiology, even when not interacting or even being continuously together? McClintock's work on social chemosignals provides some evidence for the latter possibility (e.g., McClintock, 2002), as does Hofer's (1984) suggestion that some of the sequelae of spousal bereavement—such as sleep disturbance, loss of appetite, and social withdrawal—might proceed from the loss of a cohabitating partner's influence on regulatory systems and routines. One way to better understand the mechanisms fueling coregulation is to look at within-couple associations in mood and physiology over time, in settings when partners are and are not together. The question of whether spouses show physiological coregulation in everyday life has been essentially unexplored; most research on within-couple physiology, like the marital conflict studies cited above, has focused only on discrete, laboratory-based interactions explicitly designed to test partners' responses to social engagement. However, emotion researchers using repeated-measures designs have found compelling evidence for within-couple emotion transmission in everyday life (Butner et al., 2007; Larson & Almeida, 1999). For example, a study of couples' moods across 7 days found that one spouse's changes in anger and sadness were associated with changes in the other partner's mood when the couple reunited after a period of time apart (Schoebi, 2008). A daily diary study found that cohabitating partners covaried both in their day-to-day levels of positive and negative affect and in their cycles of affective change over time (Butner et al., 2007). A within-subjects, repeated-measures approach to physiological coregulation is clearly warranted in order to complement these intriguing early findings from the emotion literature. In the following section, we introduce the hypothalamic–pituitary–adrenal (HPA) axis, a system that we consider to be especially well suited to the study of partners' coregulation in daily life.

The HPA Axis

The hypothalamic–pituitary–adrenal (HPA) axis is one of the body's key stress-responding systems, and its end product, cortisol, has been established across a wide body of studies as a marker of both perceived and objective stress, challenge, and threat. The HPA axis has been linked with allostatic load, or the cumulative "price of adaptation" to chronic stressors, and may affect health and mortality through pathways including immune functioning, metabolism, blood pressure, and cognition (McEwen, 1998). The HPA axis also appears to be specifically sensitive to social inputs, including social evaluative threat (Dickerson & Kemeny, 2004); momentary social contacts, or "social zeitgebers" (Stetler, Dickerson, & Miller, 2004); and social support (Kirschbaum, Klauer, Filipp, & Hellhammer, 1995). Marital quality and attachment style have also been linked with HPA axis functioning, both in terms of reactivity to laboratory-based conflict interactions (e.g., Kiecolt-Glaser et al., 1993; Kiecolt-Glaser et al., 1996; Malarkey, Kiecolt-Glaser, Pearl, & Glaser, 1994; Powers, Pietromonaco, Gunlicks, & Sayer, 2006) and in daily life (e.g., Adam & Gunnar, 2001; Saxbe, Repetti, & Nishina, 2008). Due to its sensitivity to both social threat and social support, the HPA axis appears to be a fruitful physiological system to target in studying within-couple processes. Additionally, since salivary cortisol sampling can be incorporated into ambulatory research protocols, it is optimal for the study of coregulation processes over time and in everyday life. Importantly, cortisol has a strong diurnal cycle, typically peaking shortly after waking and declining over the course of the day. Therefore, any investigation of predictors of within-person change in cortisol must consider and control for sampling time.

Only a few published studies have looked at correspondences in HPA activity within couples or families. A study of expectant parents found inconsistent associations between spouses' cortisol and other hormone levels leading up to the birth, although only 9 couples were sampled and wives' pregnancy may have affected results (Berg & Wynne-Edwards, 2002). Another study found modest positive correlations in afternoon cortisol between parents and children and between spouses (Schreiber et al., 2006). To our knowledge, no published studies have tracked within-couple associations in cortisol sampled over multiple time points or days, despite the dynamic nature of the HPA axis and its strong diurnal rhythm. Marital conflict studies examining physiological linkage within couples, like those cited above, have chiefly concentrated on measures of sympathetic arousal, like heart rate and skin conductance; few studies have focused on HPA axis activation, despite the large and growing research literature establishing cortisol as a reliable marker of stress. Although it is likely that cortisol patterns would parallel those of other physiological systems, this assumption has received only mixed support in the literature and requires further exploration.

Additionally, no studies have examined the possible moderating role of relationship quality on spouses' physiological coregulation in everyday life. Research on marital conflict suggests that couples with more closely coordinated levels of psychophysiological arousal are more vulnerable to distress, evidently because of their reactivity to each other's stress or negative affective states (e.g., Levenson & Gottman, 1983). However, it is unclear whether partners' patterns of arousal during conflict would apply to coregulation processes in daily life.

Affective Coregulation

As discussed above, more is known about the interplay between spouses' affective states than that between their physiological states. Emotion transmission research (reviewed by Larson & Almeida, 1999) has reported on positive associations between family members' momentary emotions. Additionally, negative feelings, such as anger or frustration, appear to be more "contagious" than positive ones within families. Several studies have found links between one spouse's stressful experiences and the other spouse's self-reported psychological distress (e.g., Bolger, DeLongis, Kessler, & Wethington, 1989; Chan & Margolin, 1994; Westman & Vinokur, 1998). However, research comparing husbands and wives has been inconclusive about which partner is more likely to influence the spouse's emotional state (e.g., Almeida, Wethington, & Chandler, 1999; Larson & Richards, 1994; Parasuraman, Greenhaus, & Granrose, 1992).

The study of moderators in affective coregulation remains preliminary. For example, might relationship quality amplify or buffer the transfer of emotions between partners? Research to date has been limited but has suggested that families who lack positive resources—such as families with high levels of neuroticism, chronic stress, or marital distress—may be most vulnerable to the transmission of negative affect from one family member to another (e.g., Larson & Almeida, 1999) or may be more affected by partners' outside stress (e.g., Bumpass, Crouter, & McHale, 1999; Story & Repetti, 2006). Attachment style also appears to moderate affective coregulation between partners; for example, anxiously attached men showed lower covariation with their partners' negative affect when their partners were also anxiously attached, whereas avoidantly attached partners were less influenced by changes in their partners' cycles of positive affect (Butner et al., 2007).

The Current Study

The study of physiological and emotional coregulation within couples brings up many unanswered issues. For example, most studies of physiology within a close relationship context have focused either on one individual at a time or on controlled, laboratory-based interactions; no study has yet examined how spouses' physiological states might be correlated across several occasions within a day or across days, and few studies have concentrated specifically on HPA axis functioning. It is also unclear how relationship quality might affect the direction or magnitude of associations between spouses' physiological or emotional states. Finally, although it seems intuitive that spouses' mood and cortisol levels would be more highly correlated when partners are in close proximity—that is, when they are physically together in a shared space—this assumption has not yet been tested in the case of physiology and has only begun to be explored in the case of affect (e.g., Schoebi, 2008). For example, Butner and colleagues (2007) reported that on days couples spent more hours together, covariation in levels of positive and negative emotions was greater.

For the present study, mood and cortisol data were collected from a sample of dual-earner couples on multiple occasions on three days at work and at home. This article examines three hypotheses concerning associations between partners' cortisol levels and mood states. Tests of the first two hypotheses included all data points from three days of cortisol and mood sampling, working from the assumption that coregulation between spouses might express itself through daily rhythms and consequently appear even when spouses are not physically together. The third hypothesis explicitly put this assumption to the test, comparing associations between spouses' mood and cortisol when sampled at home and at work.

Hypotheses

Hypothesis 1: Over three days of study, fluctuations in husbands' and wives' cortisol levels will be positively associated with each other after controlling for sampling time. In other words, for each sampling occasion on which a husband has a higher-than-usual cortisol level, his wife will also have a higher-than-usual cortisol level. Additionally, the association between husbands' and wives' cortisol levels will be moderated by marital satisfaction. Although findings in the literature have been inconsistent about relationship quality and coregulation, in keeping with the negative affect reciprocity model (Levenson & Gottman, 1983), we predict that less maritally satisfied couples will show stronger within-couple associations in cortisol.

Hypothesis 2: Spouses will show coregulation of momentary mood states. Therefore, husbands' and wives' ratings of their moods, both positive and negative, will be positively associated with each other. The emotion transmission literature has reported greater contagion of negative than positive affect (Larson & Almeida, 1999). In keeping with this finding, the covariation of spouses' positive moods may be weaker than the covariation of spouses' negative moods. As with cortisol, and given preliminary evidence that families lacking positive resources show stronger contagion of negative affect (e.g., Larson & Almeida, 1999), marital satisfaction will moderate the strength of the association between spouses' negative moods, such that less maritally satisfied couples will show more strongly linked negative moods. No prediction is made for the moderation of positive mood coregulation, given the lack of prior evidence.

Hypothesis 3: Associations between spouses' mood states, and also between their cortisol levels, will be strongest in the early morning and evening, when spouses are in a shared environment, and weakest in the late morning and afternoon, when spouses are at work.

Hypothesis 4: Within-couple coregulation will be linked across systems (mood and cortisol), such that spouses with stronger levels of cortisol coregulation will also show stronger mood coregulation.

To explore these questions, we used multilevel modeling techniques and employed a couples-level approach described by Laurenceau and Bolger (2005). In other words, models included separate intercept and slope terms for husbands and wives to account for interdependency within couples. Dyadic multilevel modeling is a statistical approach that simultaneously adjusts for the nesting of samples within individuals and the nesting of individuals within couples.

Method

Participants

Thirty-two families in a southwestern U.S. city were recruited for a larger study of everyday life within dual-earner middle class families. Each family included two cohabiting adults, both of whom worked full-time (at least 30 hr per week), and each family included two to three children, one of whom was between 8 and 10 years of age at the time of the study.

Of the 60 adults included in the final sample,[1] the median age was 41 years for both men and women, with a range of 32–58 years among men and of 28–50 years among women. Families averaged 2.3 children (median = 2). The duration of marriage for couples in the study ranged from 3 to 18 years (median = 13). The majority of couples were Caucasian, but the sample also included East Asian, Latino, African American, and South Asian couples. The median annual family income was $100,000 (range = $51,000–$196,000 in 2002–2005 dollars). No couples shared the same workspace.

Procedure

The study sought to capture a "week in the life" of each family and included videotaping and physical tracking of family members while at home. This study focuses on the adults' daily diary portion of the study: On each of three separate weekdays during the study week (not necessarily consecutive days), spouses completed four self-report measures of mood and provided four self-collected saliva samples for cortisol analysis.

Cortisol collection. Spouses were instructed to self-collect saliva samples and report collection times at these four time points: (1) early morning, upon awakening; (2) late morning, just before lunch; (3) afternoon, just before leaving work; and (4) evening, before going to bed. Mean collection times were 6:25 a.m. (early morning), 12:20 p.m. (late morning), 4:30 p.m. (afternoon), and 10:10 p.m. (evening). The standard deviation of collection time across all participants was largest in the afternoon (87 min) and smallest in the morning (49 min).

Before the study week began, equipment for collecting saliva (labeled 5-mL screw-cap cryogenic vials, straws, thermoses, and reminder beepers), along with daily self-report questionnaire forms, was dropped off at families' homes by a research assistant who also reviewed instructions for saliva sampling and storage with participants and programmed the reminder beepers.

Participants were asked not to eat or drink anything other than water in the half hour preceding saliva collection. If they indicated on their diary form that they had eaten within half an hour of saliva collection, then that sample was eliminated from analyses. Participants were also asked to record the time of each sampling, as well as any medications consumed or cigarettes smoked during the preceding hours; these data were used as a control variable in these analyses. Parents were given thermoses in which to keep saliva vials collected at work and were asked to refrigerate the vials until they were picked up by a research assistant the following day. Saliva vials were then frozen and shipped under climate-controlled conditions to Salimetrics, a research facility specializing in saliva immunoassay testing.[2] To correct for positive skewness, we performed a natural log transformation on cortisol data before analysis.

Mood reports. At the same times they sampled saliva, spouses filled out mood rating scales, indicating how well a series of adjectives described their current mood. Developed and revised in other daily report studies (Repetti, 1989; Repetti & Wood, 1997), the 25 items include adjectives like "frustrated," "energetic," and "miserable." Separate scores were calculated for negative mood and positive mood. The positive mood score was comprised of the four adjectives "playful," "kindly," "elated," and "energetic," and the negative mood score was composed of 11 adjectives, including "tense," "angry," and "sad." Cronbach's alpha for the mood scales ranged from .79 to .85 over the three days of saliva collection.

Marital Adjustment Test. The Marital Adjustment Test (MAT), which spouses filled out following completion of the study week, is a 16-item measure, found to have split-half reliability of .90, that assesses spouses' satisfaction with their marriage (Locke & Wallace, 1959). The MAT has been used extensively by marital researchers. Cronbach's alpha in this study was .82 for women and .81 for men. In this sample, both the mean and median score was 111 (range = 64–154), with a median of 116 for men (range = 67–150) and a median of 109 for women (range = 64–154). This is consistent with other studies using the MAT

[1] Two gay male couples were excluded, given the potential relevance of gender to the results.

[2] Samples were assayed with a highly sensitive enzyme immunoassay—US FDA (510k)—cleared for use as an in vitro diagnostic measure of adrenal function (Salimetrics, State College, PA). The test used 25 μl of saliva and had a lower limit of sensitivity of .007 μg/dl (micrograms per deciliter), a range of sensitivity from .007 μg/dl to 1.8 μg/dl, and average intra- and interassay coefficients of variation of less than 5% and 10%, respectively. The average of duplicate assays for each sample was used in all analyses.

(e.g., Karney & Bradbury, 1997), which have found average scores typically around 115. Husbands' and wives' MAT scores were positively correlated, $r(29) = .48$, $p < .01$. Before analyzing these data, we divided scores by the standard deviation of MAT (20.37 for husbands, 23.79 for wives) so that each one-unit change would represent a standard deviation change in MAT score.

Analysis of Cortisol Data

All data were analyzed with hierarchical linear modeling (HLM), Version 6.01 (Raudenbush, Bryk, & Congdon, 2004). Multilevel modeling is ideal for representing how variables change across time and how those changes are associated with trait-level (between-person) and state-level (within-person) factors. HLM is optimal for cortisol analysis (Hrushka, Kohrt, & Worthman, 2005) because of the strong diurnal slope of cortisol. Additionally, HLM is able to calculate slopes and intercepts even when some values are missing, so that (a) there do not need to be equal numbers of observations across individuals for data analysis to be performed, and (b) observations do not need to be evenly spaced (Hrushka et al., 2005).[3]

Each participant's mood and cortisol were modeled with data from all 12 sampling occasions, with the time of day at which each sampling occasion occurred used as a predictor variable. In other words, the three days of data collection, each with four saliva or mood sampling time points, can be conceptualized as one day with 12 sampling time points, and each mood or cortisol value at any given time of day can be tested as a deviation from the expected value, given the overall "slope" of mood and cortisol across the day. This is a common strategy used by researchers using multilevel modeling to study cortisol (Adam, 2006; Adam & Gunnar, 2001; Saxbe et al., 2008; Smyth et al., 1997) and was adopted in this study after high intraindividual stability in levels of mood and cortisol over the three days was established. Participants' cortisol, mood, time, and time-squared variables were group-centered in SPSS before being entered into HLM so that their values would represent deviations from each participant's individual means.

To account for statistical interdependence within couples, we conducted all analyses with the dyadic analysis model presented by Laurenceau and Bolger (2005), which is based on the model described by Raudenbush, Brennan, and Barnett (1995).[4] Models used input data files with husbands' and wives' data input on separate lines and nested within couple-level IDs. Separate intercept and slope terms were created for husbands and wives, with spouses denoted by dummy variables that were used to calculate intercepts.[5] All HLM results reported here represent the final estimation of fixed effects, with robust standard errors. Table 1 presents basic descriptive information on the marital satisfaction, mood, and cortisol variables.

Table 1
Descriptives and Within-Couple Correlations for Principal Variables

Group and variable	*M*	*SD*	Range	Correlation with spouse
Husbands				
Marital satisfaction	116	20.37	67 to 150	0.48**
Negative mood	1.26	0.27	1 to 2.64	0.21**
Positive mood	1.44	0.35	1 to 2.50	−0.03
Logged cortisol	−1.91	0.99	−4.14 to 0.46	0.65**
Wives				
Marital satisfaction	109	23.79	64 to 154	
Negative mood	1.30	0.28	1 to 3.00	
Positive mood	1.45	0.37	1 to 2.75	
Logged cortisol	−2.01	1.00	−4.71 to 0.26	

** $p < .01$.

Results

Hypothesis 1: Associations Between Spouses' Cortisol

The first hypothesis predicted that husbands' and wives' cortisol levels would be positively associated with each other at each sampling occasion across the three days of study and that this association would be moderated by marital satisfaction. This hypothesis was tested by constructing a series of models in HLM for which logged cortisol was the outcome variable and separate intercept and slope terms were used for husbands and wives. First, an unconditional model (with no predictors included at Level 1 or Level 2) was created. Second, partner cortisol level was added as a Level 1 predictor. Next, control variables including time of day parameters (time and time-squared, given the curvilinear decline of cortisol across the day) and a dummy variable reflecting potential sources of error in the saliva sample (e.g., endorsing smoking, bleeding gums, taking medication, or having any other problems with sampling procedures) were also added at Level 1. Finally, spouses' marital satisfaction scores were added as Level 2 predictors to the second and third models. For brevity, only the final model (including control variables at Level 1 and marital satisfaction at Level 2) is presented here, but all results are available on request.

The complete Level 1 equation was

$$Y_{ij} = \pi 0_i HUSB + \pi 0_i WIFE + \pi 1_i HTime_{ij} + \pi 1_i WTime_{ij} + \pi 2_i HTime^2_{ij} + \pi 2_i WTime^2_{ij} + \pi 3_i HSali_{ij} + \pi 3_i WSali_{ij} + \pi 4_i WHcortisol_{ij} + \pi 4_i HWcortisol_{ij} + \varepsilon_{ij},$$

in which Y_{ij} is the individual i's cortisol level at sampling occasion j; *HUSB* and *WIFE* are dummy variables indicating husbands' and wives' data, and $\pi 0_i$, for example, is the model intercept for each spouse; *H* refers to husband, and *W* refers to wife; *Time* refers to the time of day, in military time; $Time^2$ is the time variable, squared; *Sali* is the dummy code for any saliva sampling problems;

[3] Altogether, 70 cortisol observations, or 9.7% of the 720 sampling occasions, were missing from the data set (in most cases because the saliva collection was skipped, but in some cases the saliva was sampled incorrectly, e.g., within 30 min of eating).

[4] For analyses of individual participants' cortisol levels across days, see Saxbe et al. (2008).

[5] Testing the influence of one partner's cortisol or mood level on the other partner's cortisol or mood level requires special statistical treatment because the same variable can serve as both a predictor and an outcome. This problem was addressed by using cross-spouse predictor variables with husbands' data on wives' lines and vice versa, as suggested by Niall Bolger (personal communication, 2007).

WHcortisol is the variable representing wives' cortisol level as a predictor of husbands' cortisol level at the same sampling occasion (wives' cortisol level, with husbands' cortisol as the dependent variable and wives' dummy-coded intercept variable = 0); *HWcortisol* represents husbands' cortisol level as a predictor of wives' cortisol level at the same sampling occasion (husbands' cortisol level, with wives' cortisol as the dependent variable and husbands' dummy-coded intercept variable = 0), and ε_{ij} represents within-couple error.

To test the possible moderating role of marital satisfaction on this association, we added spouses' Marital Adjustment Test (MAT) scores at Level 2. In two-level HLM models, Level 2 is typically used for between-person variables; adding these scores generated two additional equations for both wives and husbands. For example, the Level 2 equation defining the influence of wives' cortisol level on husbands' cortisol level, $\pi 1_i$, is

$$\pi 1_i = \gamma 10 + \gamma 11(\text{HusbandMAT}) + u1_i,$$

where $\pi 1_i$ is predicted by $\gamma 10$, the average slope of partner cortisol affecting own cortisol among the husbands (i.e., the average change in husbands' cortisol produced by each one-unit change in wives' cortisol), and $\gamma 11$(HusbandMAT), which reflects the overall difference in that slope as a function of husbands' marital satisfaction score. Likewise, $\pi 1_i HWcortisol_{ij}$ is modeled as a function of $\gamma 10$, the overall change per unit of wives' cortisol produced by each one-unit change in husbands' cortisol, and $\gamma 11$(WifeMAT), the added increase or decrease in that slope attributable to wives' marital satisfaction scores.

Results of the model are shown in Table 2. The coefficients presented in the table can be interpreted similarly to linear regression coefficients, representing the change in the outcome variable produced by changes in the predictors. As hypothesized, spouses appeared to show coregulation of cortisol levels over several days: For both spouses, partner cortisol was significantly and positively associated with own cortisol after controlling for time of day and sampling conditions.[6] In other words, for any sampling occasion for which wives' cortisol was higher than usual, husbands' cortisol also tended to be higher than usual (β = .28, $p < .05$). Similarly, higher-than-usual husbands' cortisol predicted higher-than-usual cortisol in wives (β = .16, $p < .001$). For both wives and husbands, marital satisfaction moderated the strength of the association between spouses' cortisol. The significant negative beta associated with both husbands' and wives' MAT suggests that less maritally satisfied spouses had cortisol levels that were more strongly correlated with their partners' cortisol over time. Figure 1 depicts this result for wives, showing the association between husbands' and wives' momentary cortisol levels for wives at the mean for marital satisfaction and estimated at one standard deviation above and below the mean. As illustrated in the figure, the less maritally satisfied women had the steepest slope; their cortisol levels were most closely tied to their husbands' cortisol levels.

Table 2
Partner Cortisol Predicting Own Cortisol Level

Fixed effect	Coefficient (*SE*)	*t* ratio
Husbands' intercept ($\pi 0_i HUSB$)	−0.02 (0.02)	−0.76***
Wives' intercept ($\pi 0_i WIFE$)	0.00 (0.03)	0.82***
Slope of husbands' time[a] ($\pi 1H$)	−1.75 (0.46)	−3.77***
Slope of husbands' time[2b] ($\pi 2H$)	1.26 (0.41)	3.05***
Slope of husbands' saliva sampling error ($\pi 3H$)	0.03 (0.07)	0.38
Slope of wives' time[c] ($\pi 1W$)	−1.39 (0.27)	−5.06***
Slope of wives' time[2d] ($\pi 2W$)	0.64 (0.29)	2.23*
Slope of wives' saliva sampling error ($\pi 3W$)	0.11 (0.11)	1.04
Partner (husband) cortisol predicting wives' cortisol ($\pi 4HW$)	0.16 (0.05)	3.18***
Level 2 effect of wives' MAT score ($\gamma 11$)	−0.05 (0.02)	−2.15*
Partner (wife) cortisol predicting husbands' cortisol ($\pi 4WH$)	0.28 (0.12)	2.33*
Level 2 effect of husbands' MAT score ($\gamma 11$)	−0.07 (0.03)	−2.30*

Note. MAT = Marital Adjustment Test.
[a] Change in cortisol per 1-hr change in time. [b] Change in cortisol per one-unit change in time^2. [c] Change in cortisol per 1-hr change in time. [d] Change in cortisol per one-unit change in time^2.
* $p < .05$. *** $p < .001$.

In a follow-up analysis, we also tested whether one partner's marital satisfaction moderated the other partner's coregulation by adding husbands' MAT (at Level 2) to the slope of husbands' cortisol predicting wives' cortisol, and wives' MAT to the slope of wives' cortisol predicting husbands' cortisol. We found that husbands' marital satisfaction moderated the effect of husbands' cortisol on wives' cortisol (β = −.11, $p < .001$), in the same direction as the result for wives' own marital satisfaction. However, wives' marital satisfaction did not appear to significantly moderate the effect of wives' cortisol on husbands' cortisol (β = –.04, $p > .50$).

Hypothesis 2: Associations Between Spouses' Moods

The same steps used to test Hypothesis 1 were followed in testing spouses' mood states. In other words, we created an HLM model that included partner mood level as a Level 1 predictor. Time of day was added a control variable (we did not need to include time-squared because there is no evidence that the trajectory of mood is curvilinear). Next, spouses' marital satisfaction scores were added at Level 2. We present results first for negative mood ratings and then for positive mood ratings.

Negative mood. As shown in Table 3, husbands' and wives' negative mood levels were positively associated with each other, such that an increase in husbands' self-reported negative mood was associated with an increase in wives' negative mood (β = .17, $p < .05$), and wives' higher-than-usual negative mood was associated with husbands' higher-than-usual negative mood (β = .13, $p < .05$). Also, as with the Level 2 results reported above for cortisol, the Level 2 results indicated that, for husbands, partners' negative mood states were more strongly linked among less maritally satisfied couples. This result is depicted graphically in Figure 2. As in the first figure, the husbands with lower marital satisfaction scores showed the strongest couple correspondence in cortisol.

[6] Partner cortisol was also significantly associated with own cortisol for both spouses when sampling time and sampling conditions were not included in the model. Another model was tested that included partners' sampling time and time-squared as controls in addition to own time and time-squared, and the pattern of results was the same (spouses' cortisol levels continued to be significantly associated). Both set of results are available upon request.

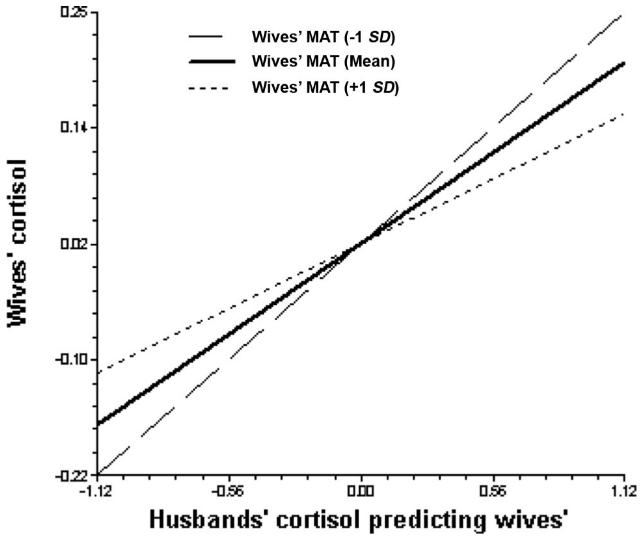

Figure 1. Husbands' cortisol predicting wives' cortisol, as moderated by wives' marital satisfaction, as measured by the Marital Adjustment Test (MAT). This figure, generated by hierarchical linear modeling 6.01, depicts within-subject associations between husbands' log-transformed cortisol and wives' log-transformed cortisol for wives (n = 30 wives) with MAT scores at the sample mean and estimated at ±1 standard deviation from the mean.

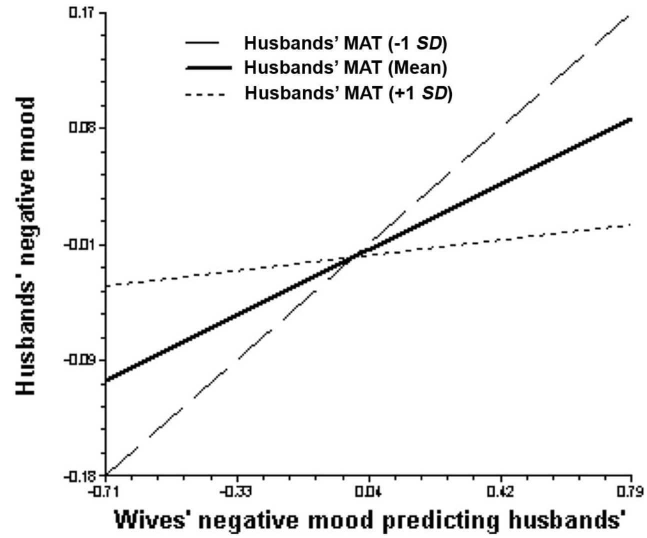

Figure 2. Wives' negative mood rating predicting husbands' negative mood rating, as moderated by husbands' marital satisfaction, as measured by the Marital Adjustment Test (MAT). This figure, generated by hierarchical linear modeling 6.01, depicts within-subject associations between wives' negative mood rating and husbands' negative mood rating for husbands (n = 30 husbands) with MAT scores at the sample mean and estimated at ±1 standard deviation from the mean.

We also followed up on this analysis by adding one spouse's MAT (at Level 2) to the slope predicting the other partner's negative mood. We found that husbands' marital satisfaction moderated the effect of husbands' negative mood on wives' negative mood ($\beta = -.12$, $p < .05$), in the same direction as the result for husbands' marital satisfaction predicting the effect of wives' negative mood on husbands' negative mood. However, wives' marital satisfaction did not appear to significantly moderate the effect of wives' cortisol on husbands' cortisol ($\beta = -.04$, $p > .50$).

Positive mood. Husbands' and wives' positive mood levels were not significantly associated with each other, whether or not marital satisfaction was included in the model, and marital satisfaction did not appear to moderate associations in positive moods between spouses.

Table 3
Partner Negative Mood Predicting Own Negative Mood, With Marital Satisfaction Included at Level 2

Fixed effect	Coefficient (*SE*)	*t* ratio
Husbands' intercept ($\pi 0_i HUSB$)	−0.03 (.02)	−1.68†
Wives' intercept ($\pi 0_i WIFE$)	0.01 (.02)	0.32
Slope of husbands' time[a] ($\pi 1H$)	−0.03 (.06)	0.50
Slope of wives' time[a] ($\pi 1W$)	0.11 (.07)	1.61
Partner (husband) mood predicting wives' mood ($\pi 1HW$)	0.17 (0.06)	2.67*
Level 2 effect of wives' MAT score ($\gamma 11$)	−0.03 (.04)	−0.73
Partner (wife) mood predicting husbands' mood ($\pi 1WH$)	0.13 (0.06)	2.23*
Level 2 effect of husbands' MAT score ($\gamma 11$)	−0.10 (.04)	−2.31*

Note. MAT = Marital Adjustment Test.
[a] Change in negative mood per 1-hr change in time.
† $p < .10$. * $p < .05$.

Hypothesis 3: Strength of Spouses' Associations When Together or When Apart

To test whether spouses show stronger coregulation—specifically, more strongly associated negative mood and cortisol—when in a shared environment, we divided the three days of mood and cortisol data into two separate data sets: home (i.e., the early morning and evening samples) and work (i.e., the late morning and afternoon samples, taken during the workday). The associations between couples' cortisol and mood were then tested separately within each data set.[7] Only cortisol and negative mood were tested in this way, since spouses' positive moods were not significantly associated.

As shown in Table 4, spouses' cortisol was significantly associated within the home data set. In contrast, associations between husbands' and wives' cortisol were nonsignificant in the work data set. Similarly, as shown in Table 5, spouses' negative mood levels were significantly positively associated within the home data set (although the association for husbands was at a marginal level of significance), but the associations between spouses was nonsignificant within the work data set. Therefore, it appears that, as expected, the results reported above were driven by the data

[7] The associations between spouses' mood and cortisol levels were also tested separately at each time point (early morning, late morning, afternoon, and evening), but since the pattern of results were substantively the same as when early morning/evening and late morning/afternoon samples were combined, these results are not discussed here.

Table 4
Partner Cortisol Level Predicting Own Cortisol Level, Sampled in Work and Home Settings

Fixed effect	Coefficient (*SE*)	*t* ratio
Early morning and evening samples (home data set)		
Husbands' intercept ($\pi 0_i HUSB$)	0.27 (0.11)	2.37
Wives' intercept ($\pi 0_i WIFE$)	0.11 (0.10)	1.10
Slope of husbands' time ($\pi 1H$)	0.64 (0.76)	0.85
Slope of husbands' time^2 ($\pi 2H$)	−0.99 (0.75)	−1.31
Slope of wives' time ($\pi 1W$)	−0.61 (0.75)	−0.81
Slope of wives' time^2 ($\pi 2W$)	−0.17 (0.73)	−0.24
Partner (husband) cortisol predicting wives' cortisol ($\pi 3HW$)	0.18 (0.07)	2.72**
Partner (wife) cortisol predicting husbands' cortisol ($\pi 3WH$)	0.42 (0.12)	3.52***
Late morning and afternoon samples (work data set)		
Husbands' intercept ($\pi 0_i HUSB$)	−0.32 (0.17)	−1.94†
Wives' intercept ($\pi 0_i WIFE$)	−0.02 (0.19)	−0.01
Slope of husbands' time ($\pi 1H$)	0.14 (1.03)	0.14
Slope of husbands' time^2 ($\pi 2H$)	−0.64 (1.00)	−0.64
Slope of wives' time ($\pi 1W$)	−1.31 (1.13)	−1.16
Slope of wives' time^2 ($\pi 2W$)	0.96 (1.04)	0.92
Partner (husband) cortisol predicting wives' cortisol ($\pi 3HW$)	0.05 (0.07)	0.68
Partner (wife) cortisol predicting husbands' cortisol ($\pi 3WH$)	0.04 (0.06)	0.67

† $p < .10$. ** $p < .01$. *** $p < .001$.

collected when spouses were in a shared environment. There was no evidence for coregulation of cortisol or negative mood levels when spouses were in different settings.

Hypothesis 4: Associations Between Mood Coregulation and Cortisol Coregulation

The final hypothesis explored whether couples' coregulation in one response system might be associated with their coregulation in another system—for example, whether mood coregulation is linked with cortisol coregulation, and vice versa. In order to test this hypothesis, we used a two-step analytic strategy. First, we ran the three HLM models described above, predicting cortisol, negative mood, and positive mood in turn. In each case, the Level 2 residual file was saved. From these files, the empirical Bayesian (EB) estimates of the Level 1 coefficients for each couple (husbands' values predicting wives' values, and wives' values predicting husbands' values) were computed. These estimates represent the strength of the overall association between one spouse's values and the other's values, or the degree of coregulation within each response system (cortisol, negative mood, and positive mood) for each participating couple.

Simple correlations were then calculated with these coregulation slope estimates. The EB estimates for negative mood coregulation and cortisol coregulation were positively correlated, $r(29) = .42$, $p < .05$, suggesting that couples showing coregulation in one response system were more likely to show coregulation in the other system. The EB estimates for positive mood and cortisol were not correlated, $r(29) = .22$, $p > .10$, nor were the EB estimates for positive mood coregulation and negative mood coregulation, $r(29) = .13$, $p > .50$. We also tested associations between the coregulation estimates and marital satisfaction scores in order to follow up on our finding that marital satisfaction moderated coregulation at Level 2 for cortisol and negative mood. Husbands' marital satisfaction was negatively correlated with the cortisol coregulation EB estimates, $r(29) = -.51$, $p < .01$, and, at a trend level, with the negative mood coregulation EB estimates, $r(29) = -.33$, $p < .10$, but not with the positive mood coregulation estimates, $r(29) = -.20$, $p > .10$. These first two associations are consistent with the negative betas found for marital satisfaction at Level 2 in the analyses presented in Tables 2 and 3, suggesting that less satisfied husbands have stronger within-couple associations of negative mood and cortisol. Wives' marital satisfaction was not associated with the cortisol coregulation estimates, $r(29) = -.18$, $p > .10$; negative mood coregulation estimates, $r(29) = -.09$, $p > .50$; or positive mood coregulation estimates, $r(29) = .03$, $p > .50$.

Discussion

This study found husbands' and wives' cortisol levels to be positively associated over several days of study, whether or not the time of saliva sampling was controlled. In other words, for any sampling occasion in which one member of the couple showed higher-than-usual cortisol, the other was likely to show higher-than-usual cortisol as well, suggesting that spouses' trajectories of within-person change in cortisol over several days are linked. For both husbands and wives, marital satisfaction decreased the strength of this association. In other words, spouses who reported greater marital dissatisfaction appeared to have cortisol patterns that were more closely linked to their partners'. Similarly, husbands' and wives' negative moods were positively associated with each other over several days. For husbands, marital satisfaction weakened the within-couple association between negative moods, such that wives' levels of negative mood appeared to more

Table 5
Partner Negative Mood Predicting Own Negative Mood, Sampled in Work and Home Settings

Fixed effect	Coefficient (*SE*)	*t* ratio
Early morning and evening samples (home data set)		
Husbands' intercept ($\pi 0_i HUSB$)	−0.08 (0.06)	−1.25
Wives' intercept ($\pi 0_i WIFE$)	0.07 (0.04)	1.67
Slope of husbands' time ($\pi 1H$)	−0.05 (0.06)	−0.85
Slope of wives' time ($\pi 1W$)	0.15 (0.07)	2.21*
Partner (husband) mood predicting wives' mood ($\pi 1HW$)	0.22 (0.10)	2.26*
Partner (wife) mood predicting husbands' mood ($\pi 1WH$)	0.17 (0.10)	1.69†
Late morning and afternoon samples (work data set)		
Husbands' intercept ($\pi 0_i HUSB$)	−0.01 (0.09)	−0.12
Wives' intercept ($\pi 0_i WIFE$)	0.06 (0.07)	−0.87
Slope of husbands' time ($\pi 1H$)	−0.29 (0.24)	−1.21
Slope of wives' time ($\pi 1W$)	−0.30 (0.26)	−1.15
Partner (husband) mood predicting wives' mood ($\pi 1HW$)	0.10 (0.10)	1.05
Partner (wife) mood predicting husbands' mood ($\pi 1HW$)	0.04 (0.11)	0.34

† $p < .10$. * $p < .05$.

strongly predict the negative moods of less satisfied husbands. Couples' positive moods did not appear to be associated, regardless of whether marital satisfaction was included in the model. Additionally, when mood and cortisol samples taken before and after the workday were compared with samples taken during the workday, spouses' mood and cortisol were associated only in the morning and evening, when couples were in a shared environment. Finally, the degree of overlap between cortisol coregulation and mood coregulation was explored. Slope estimates for the degree of coregulation in cortisol and negative mood were positively associated with each other, suggesting that couples whose momentary fluctuations in cortisol resemble each other more closely are also couples whose negative moods are more tightly linked as well. These slope estimates were also negatively associated with husbands' marital satisfaction, although they were not linked with wives' marital satisfaction.

These findings were generated with a dyadic multilevel modeling approach that allows for the simultaneous testing of within-couple effects (examining patterns of change within couples) and between-person effects (exploring whether some partners show stronger within-couple associations than do others). Therefore, in interpreting these results, it is important to understand that the Level 1 concordance in cortisol and mood is not attributable to assortative mating or similarities in personality that might make a couple's cortisol levels higher or lower than those of the average couple. Instead, within each couple, husbands' and wives' fluctuations around their own average cortisol and mood levels were linked.

This is the first article, to the authors' knowledge, to report that husbands' and wives' cortisol levels are associated over several days in a naturalistic setting. If this finding is borne out by further study, it may have important implications for health and well-being in adulthood. Most adults cohabit with a close relationship partner, but little is known about the physiological concomitants of this cohabitation. While dozens, even hundreds, of studies have examined the effect of individual stressors and personality characteristics on cortisol, this result is the first to indicate that partners' daily HPA axis fluctuations may show signs of synchrony or bidirectional influence. Given that cortisol rhythms have been linked to allostatic load processes (i.e., the wear and tear brought on by chronic stress; e.g., McEwen, 1998) and even to disease progression and mortality (Sephton, Sapolsky, Kraemer, & Spiegel, 2000), it is important to further explore the long-term impact of coregulatory processes on HPA axis functioning.

The coregulation of both mood and cortisol levels between spouses appeared to be moderated by marital satisfaction, such that more maritally satisfied wives seemed less reactive to fluctuations in husbands' cortisol, and associations between negative mood states for both husbands and wives appeared to be strengthened by marital dissatisfaction. This pattern of results suggests either that greater marital satisfaction may buffer couples from the influence of each other's negative mood and physiological stress states or, in the converse direction, that couples who are less reactive to each other are less likely to become maritally distressed. This is consistent with the negative affect reciprocity model (Gottman et al., 1998; Levenson & Gottman, 1983), which describes unhappily married couples as being unable to disengage from each other's negative emotions, leading to escalating antagonism. Although that model was developed to explain couples' physiological arousal during short-term conflict interactions, it may also apply to the results of this study, which was conducted over several days in a naturalistic environment characterized by low levels of overt aggression. One sign of positive marital adjustment may be the ability to counteract stressful experiences or negative affect between partners, so that one partner's arousal might be met by the other's relative calm, rather than synchronizing so closely as to become locked into noxious states or interactions. Interestingly, husbands' marital satisfaction appeared to be more consistently tied to coregulation than was wives' marital satisfaction. For example, in the case of negative mood, only husbands' MAT scores significantly moderated wife-to-husband coregulation. When cross-partner marital satisfaction analyses were conducted (husbands' MAT moderating husband-to-wife coregulation and wives' MAT moderating wife-to-husband coregulation), only husbands' marital satisfaction was a significant predictor. Additionally, husbands' but not wives' marital satisfaction scores were negatively correlated with the coregulation slope estimates for cortisol and negative mood. It may be that husbands' feelings about the marriage set the tone for how spouses react to each other's negative mood and stress states. In their review of the emotion transmission literature, Larson and Almeida (1999) suggested that the distribution of power within families might shape the flow of emotions from one member to another, with husbands more likely to drive wives' emotions than vice versa. Our finding that husbands' marital satisfaction was more meaningful to within-couple coregulation appears to support this account.

Although couples' cortisol levels and negative moods were associated, couples' positive mood states did not appear to be linked, whether or not marital satisfaction was considered. Positive mood coregulation also did not appear to be associated with couples' degree of coregulation in cortisol or negative mood. The emotion transmission literature has reported that negative emotions appear to transmit more readily within families than do positive emotions and that the strength of negative emotions appears to outweigh the strength of positive ones (e.g., one spouse's sadness is more apt to reduce the other spouse's cheerfulness than the converse; Larson & Almeida, 1999). This different pattern of findings for positive and negative mood reported here may indicate greater contagion of negative mood or stress states, but it may also reflect the fact that fewer adjectives were used in the positive mood scale in this study; perhaps greater precision in measuring positive moods would have unearthed some within-couple associations.

This study started with the assumption that couples' coregulation might manifest itself in terms of daily rhythms and thus appear even when spouses are not physically together. However, the results support the conclusion that similarities in the fluctuations of partners' mood and cortisol are fueled by time spent in a shared environment. Because our sample consisted of dual-earner couples and our three days of study were all weekdays, we were able to test associations between mood and cortisol sampled in husbands' and wives' work environments as well as at home. We found that cortisol and negative mood sampled during the workday, in the late morning and afternoon, were not significantly linked, whereas spouses' early morning and evening samples were. Although it is possible that some couples were not actually together in a shared space during the first and last sampling time points of each day, other data collected during the study week indicated that both spouses were at least at home during virtually every early morning and evening sampling occasion. Indeed, one of the recruitment goals for the study was to identify families whose daily routines would be compatible enough to facilitate at-home observation.

The results for cortisol may also be attributable not to spouses' togetherness but to the importance of early morning cortisol to the overall diurnal pattern of cortisol release. Cortisol typically peaks shortly after waking and then decreases over the day, so these results may reflect the greater variability present in the early morning cortisol sample. However, sampling time was included as a covariate in these models. Also, comparisons time point by time point revealed that cortisol sampled in the evening, when cortisol typically reaches its nadir, was also significantly associated within couples. Therefore, we believe that our results reflect a true difference in the strength of coregulation during time together and time apart.

This finding has relevance to theoretical models of coregulation, since it suggests that couples' biological rhythms do not simply become entrained through cohabitation and remain entrained over periods of separation; rather, proximity is necessary to create synchrony between spouses. In other words, coregulation does not appear to be a passive phenomenon but one that may emerge from shared experience, such as social interaction or common features of the environment. Given the novelty of this line of research, these claims require much more empirical testing. For example, future research could further explore the differences in within-couple associations examined at different times of day and also examine the effect of long separations or long periods of togetherness on the strength of within-couple associations.

The finding that the slope estimates of negative mood coregulation and cortisol coregulation were associated with each other suggests that couples with more similar momentary levels of negative affect were also more likely to have more similar momentary levels of cortisol, and vice versa. This evidence of overlap in different types of coregulation supports the idea that some couples were more prone to coregulation than were others; husbands in these coregulating couples were also more likely to report marital dissatisfaction, as suggested by the negative association between marital satisfaction and the cortisol and negative mood coregulation slope estimates.

This study was limited by several weaknesses. The pool of participating couples was small (30 couples) and fairly homogeneous, in that it consisted of middle-class, dual-income families with school-age children. Further research with a larger and more diverse sample of couples is warranted. For example, it would be interesting to compare the within-couple associations of newlyweds with that of long-wed couples, or heterosexual with homosexual couples, or couples with and without children. In addition, because this is a cross-sectional study it is difficult to tease apart the direction of the moderator effects we found; more maritally dissatisfied couples may have shown stronger covariation in their negative mood and cortisol because their dissatisfaction fueled greater reactivity to each other or because their reactivity made them more vulnerable to dissatisfaction. It is also possible that a third variable, such as attachment security, could underlie both coregulation and relationship quality. That said, as a first exploration of coregulation of couples' mood and cortisol patterns, this study was well designed to minimize outside variability and focused on a demographic sample with fairly high daily stress (e.g., parents working full-time). Couples' Marital Adjustment Test scores were close to averages reported in other studies, with a broad range including distressed and extremely happy couples. The focus on cortisol and mood allows for simultaneous examination of both a physiological measure and self-report measures, enhancing the external validity of these results, and the fact that the results for cortisol and negative mood were similar, whereas couples' positive mood states did not appear to be linked, provides evidence for divergent validity.

Although the four mood and saliva sampling time points included two workday and two at-home samples, they may not have fully captured the variability in cortisol and mood states across the day. Additional sampling occasions scheduled in the morning and at the end of the workday might have further elucidated the patterns of within-couple associations. Extending the study duration beyond three weekdays could also have helped to clarify how spouses influence each other over time and revealed whether weekend and weekday effects differ. This study also relied on participants' self-report of saliva sampling time and adherence to saliva sampling procedures, which could have contributed error to the data, potentially clouding the results.

Those caveats aside, this study represents an important step forward in understanding how partners influence each other's physiology and mood. The linkages between spouses' negative mood and cortisol provide evidence for the coregulation or synchronization of couples' momentary states over time. Couples may transmit negative mood and stress to each other through aversive social interactions because they are responding to common stressors (like the misbehavior of a child or a shared financial concern) or through some other means, such as unconsciously picking up on each other's psychophysiological states and gestures while in physical proximity. In any case, naturalistic cortisol research that focuses only on individuals in isolation neglects the influences of close others and the context of the family. In addition to further exploring reciprocal influences within couples, future research could examine associations between parents and children; between siblings; and even between coworkers, roommates, or classmates. The moderating role of relationship quality is also worthy of continued study and has implications for health and well-being interventions targeted to couples. For example, given the evidence that close associations between spouses' mood and cortisol fluctuations may signal marital distress, interventions could focus on reducing partners' physiological and emotional reactivity to each other's negative states, perhaps through biofeedback, meditation, self-talk, or other coping strategies. Researchers could also track the effectiveness of marital interventions in terms of their ability to modulate or diminish within-couple associations in cortisol and mood. The possibilities are broad and exciting, given the novelty of this research area and its importance for the health of couples and families.

References

Adam, E. K. (2006). Transactions among trait and state emotion and adolescent diurnal and momentary cortisol activity in naturalistic settings. *Psychoneuroendocrinology, 31,* 664–679.

Adam, E. K., & Gunnar, M. (2001). Relationship functioning and home and work demands predict individual differences in diurnal cortisol patterns in women. *Psychoneuroendocrinology, 26,* 189–208.

Almeida, D. M., Wethington, E., & Chandler, A. L. (1999). Daily transmission of tensions between marital dyads and parent-child dyads. *Journal of Marriage and the Family, 61,* 49–61.

Anderson, C., Keltner, D., & John, O. P. (2003). Emotional convergence between people over time. *Journal of Personality and Social Psychology, 84,* 1054–1068.

Berg, S. J., & Wynne-Edwards, K. E. (2002). Salivary hormone concentrations in mothers and fathers becoming parents are not correlated. *Hormones and Behavior, 42,* 424–436.

Bolger, N., DeLongis, A., Kessler, R. C., & Wethington, E. (1989). The contagion of stress across multiple roles. *Journal of Marriage and the Family, 51,* 175–183.

Bumpass, M. E., Crouter, A. C., & McHale, S. (1999). Work demands of dual-earner couples: Implications for parents' knowledge about children's daily lives in middle childhood. *Journal of Marriage and the Family, 61,* 465–475.

Burman, B., & Margolin, G. (1992). Analysis of the association between marital relationships and health problems: An interactional perspective. *Psychological Bulletin, 112,* 39–63.

Butner, J., Diamond, L. M., & Hicks, A. M. (2007). Attachment style and two forms of affect coregulation between romantic partners. *Personal Relationships, 14,* 431–455.

Chan, C., & Margolin, G. (1994). The relationship between dual-earner couples' daily work mood and home affect. *Journal of Social and Personal Relationships, 11,* 573–586.

Diamond, L. M. (2001). Contributions of psychophysiology to research on adult attachment: Review and recommendations. *Personality and Social Psychology Review, 5,* 276–295.

Dickerson, S. S., & Kemeny, M. E. (2004). Acute stressors and cortisol responses: A theoretical integration and synthesis of laboratory research. *Psychological Bulletin, 130,* 355–391.

Feldman, R., & Eidelman, A. (2003). Skin-to-skin contact (kangaroo care) accelerates autonomic and neurobehavioural maturation in preterm infants. *Developmental Medicine & Child Neurology, 45,* 274–281.

Gallo, L. C., Troxel, W. M., Matthews, K. A., & Kuller, L. H. (2003). Marital status and quality in middle-aged women. *Health Psychology, 22,* 453–463.

Gottman, J. M., Coan, J., Carrere, S., & Swanson, C. (1998). Predicting marital happiness and stability from newlywed interactions. *Journal of Marriage and the Family, 60,* 5–22.

Hofer, M. (1984). Relationships as regulators. *Psychosomatic Medicine, 46,* 183–197.

Hrushka, D., Kohrt, B., & Worthman, C. A. (2005). Estimating between- and within-individual variation in cortisol using multilevel models. *Psychoneuroendocrinology, 30,* 698–714.

Karney, B. R., & Bradbury, T. N. (1997). Neuroticism, marital interaction, and the trajectory of marital satisfaction. *Journal of Personality and Social Psychology, 72,* 1075–1092.

Kiecolt-Glaser, J. K., Malarkey, W. B., Chee, M., Newton, T., Cacioppo, J. T., Mao, H.Y., & Glaser, R. (1993). Negative behavior during marital conflict is associated with immunological down-regulation. *Psychosomatic Medicine, 5,* 395–409.

Kiecolt-Glaser, J., & Newton, T. (2001). Marriage and health: His and hers. *Psychological Bulletin, 127,* 472–503.

Kiecolt-Glaser, J. K., Newton, T., Cacioppo, J. T., MacCallum, R. C., Glaser, R., & Malarkey, W. B. (1996). Marital conflict and endocrine function: Are men really more physiologically affected than women? *Journal of Consulting and Clinical Psychology, 64,* 324–332.

Kirschbaum, C., Klauer, T., Filipp, S., & Hellhammer, D. H. (1995). Sex-specific effects of social support on cortisol and subjective responses to acute psychological stress. *Psychosomatic Medicine, 57,* 23–31.

Kreider, R. M. (2005). Number, timing, and duration of marriages and divorces: 2001. *Current Population Reports,* 70–97. Washington, DC: U.S. Census Bureau.

Larson, R., & Almeida, D. (1999). Emotional transmission in the daily lives of families: A new paradigm for studying family process. *Journal of Marriage and the Family, 61,* 5–20.

Larson, R., & Richards, M. H. (1994). *Divergent realities: The emotional lives of mothers, fathers, and adolescents.* New York, NY: Basic Books.

Laurenceau, J., & Bolger, N. (2005). Using diary methods to study marital and family processes. *Journal of Family Psychology, 19,* 86–97.

Levenson, R. W., & Gottman, J. M. (1983). Marital interaction: Physiological linkage and affective exchange. *Journal of Personality and Social Psychology, 45,* 587–597.

Locke, H. J., & Wallace, K. M. (1959). Short marital-adjustment and prediction tests: Their reliability and validity. *Marriage and Family Living, 21,* 251–255.

Malarkey, W. B., Kiecolt-Glaser, J. K., Pearl, D., & Glaser, R. (1994). Hostile behavior during marital conflict alters pituitary and adrenal hormones. *Psychosomatic Medicine, 56,* 41–51.

Marci, C. D., Ham, J., Moran, E., & Orr, S. P. (2007). Physiologic correlates of perceived therapist empathy and social-emotional process during psychotherapy. *Journal of Nervous and Mental Disease, 195,* 103–111.

McClintock, M. (1971, January 22). Menstrual synchrony and suppression. *Nature, 229,* 244–245.

McClintock, M. K. (2002). The neuroendocrinology of social chemosignals in humans and animals: Odors, pheromones and vasanas. *Hormones, Brain and Behavior, 1,* 797–870.

McEwen, B. S. (1998). Protective and damaging effects of stress mediators. *New England Journal of Medicine, 338,* 171–179.

Parasuraman, S., Greenhaus, J. H., & Granrose, C. S. (1992). Role stressors, social support and wellbeing among two-career couples. *Journal of Organizational Behavior, 13,* 339–356.

Pietromonaco, P. R., Barrett, L. F., & Powers, S. A. (2006). Adult attachment theory and affective reactivity and regulation. In J. Simpson, D. Snyder, & J. Hughes (Eds.), *Emotion regulation in families and close relationships: Pathways to dysfunction and health* (pp. 57–74). Washington, DC: American Psychological Association.

Powers, S., Pietromonaco, P. R., Gunlicks, M., & Sayer, A. (2006). Dating couples' attachment styles and patterns of cortisol reactivity and recovery in response to a relationship conflict. *Journal of Personality and Social Psychology, 90,* 613–628.

Raudenbush, S. W., Brennan, R. T., & Barnett, R. C. (1995). A multivariate hierarchical model for studying psychological change within couples. *Journal of Family Psychology, 9,* 161–174.

Raudenbush, S. W., Bryk, A. S, & Congdon, R. (2004). *HLM 6 for Windows* [Computer software]. Lincolnwood, IL: Scientific Software International.

Repetti, R. L. (1989). Effects of daily workload on subsequent behavior during marital interaction. *Journal of Personality and Social Psychology, 57,* 651–659.

Repetti, R. L., & Wood, J. (1997). Effects of daily stress at work on mothers' interactions with preschoolers. *Journal of Family Psychology, 11,* 90–108.

Saxbe, D. E., Repetti, R. L., & Nishina, A. (2008). Marital satisfaction, recovery from work, and diurnal cortisol among men and women. *Health Psychology, 27,* 15–25.

Sbarra, D. A., & Hazan, C. (2008). Coregulation, dysregulation, self-regulation: An integrative analysis and empirical agenda for understanding adult attachment, separation, loss, and recovery. *Personality and Social Psychology Review, 12,* 141–167.

Schoebi, D. (2008). The coregulation of daily affect in marital relationships. *Journal of Family Psychology, 22,* 595–604.

Schreiber, J. E., Shirtcliff, E., Van Hulle, C., Lemery-Chalfant, K., Klein, M. H., Kalin, N. H., et al. (2006). Environmental influences on family similarity in afternoon cortisol levels: Twin and parent-offspring designs. *Psychoneuroendocrinology, 31,* 1131–1137.

Sephton, S., Sapolsky, R., Kraemer, H., & Spiegel, D. (2000). Diurnal cortisol rhythm as a predictor of breast cancer survival. *Journal of the National Cancer Institute, 92,* 994–1000.

Smyth, J. M., Ockenfels, M. C., Gorin, A. A., Catley, D., Porter, L. S., Kirschbaum, C., et al. (1997). Individual differences in the diurnal cycle of cortisol. *Psychoneuroendocrinology, 22,* 89–105.

Stetler, C., Dickerson, S. S., & Miller, G. E. (2004). Uncoupling of social zeitgebers and diurnal cortisol secretion in clinical depression. *Psychoneuroendocrinology, 29,* 1250–1259.

Story, L. B., & Repetti, R. L. (2006). Daily occupational stressors and marital behavior. *Journal of Marriage and Family Psychology, 20,* 690–700.

Uchino, B. N., Cacioppo, J. T., & Kiecolt-Glaser, J. K. (1996). The relationship between social support and physiological processes. *Psychological Bulletin, 119,* 488–531.

Westman, M., & Vinokur, A. (1998). Unraveling the relationship of distress levels within couples: Common stressors, emphatic reactions, or crossover? *Human Relations, 51,* 137–156.

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