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Chapter 8

Momentary emotions and physiological stress levels in the everyday lives of working parents

Emma K. Adam

Northwestern University

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Abstract

Recent "biosocial" perspectives on the family recognize that there are ongoing interactions between the environments in which families live, family and individual functioning and multiple aspects of their biology and physiology (Booth, Carver & Granger 2000). From this perspective, one can't understand the behavior of individuals or families without understanding their biological and physiological states, and biology and health can't be understood without reference to social contexts. Yet rarely are both family processes and biological processes well measured, and rarely have researchers investigated the relations between social and biological processes in naturalistic contexts. In this study, a subsample of 101 mothers and fathers from the Sloan Family Study provided two days of semi-random momentary diary reports in conjunction with samples of saliva, from which levels of the stress-sensitive hormone cortisol were determined. Cortisol levels were related to mothers' and fathers' momentary mood states, their feelings about the activities they were engaged in, and their location at the time of the beep – whether they were at home, in public, or at work. Using HLM growth curve modeling to control for time of day, cortisol levels were found to be higher when parents were experiencing negative emotions, lower when they experiencing positive-social emotions, when they were feeling hardworking and productive, and when they were enjoying and feeling deeply engaged in challenging activities. Feelings of productivity and engagement in activities were most frequently experienced in the work setting. Results suggest that parents' emotional experiences of their daily settings are meaningfully related to an aspect of their physiological functioning, their cortisol levels, helping to illuminate one possible pathway by which social experiences may "get under the skin" to affect health.

Introduction

In the past few decades, not only have the nature of work and family life undergone profound changes, our methods for understanding the nature of people's experiences in their work and family lives have also evolved. Social scientists are increasingly realizing that individuals experience their family and work lives not only at the cognitive and emotional levels, but also at the level of their biology. New "biosocial" perspectives on the family recognize that there are ongoing interactions between the environments in which families live, family and individual functioning, and multiple aspects of biological or physiological functioning (Booth, Carver & Granger 2000). Thus, aspects of biology, physiology, and health are recognized as one layer of the complex ecological system within which individuals function and develop. From this perspective, one can't understand behavior of individuals or families without understanding their biological and physical states, and physiological functioning and health can't be understood without reference to social context. There are many examples of the complex interactions between social context and biology, such as impacts of social relationships on cardiovascular functioning, brain development, physical growth, immune functioning and physical health (see Booth et al 2000; Cacioppo, Bernston, Sheridan & McClintock 2000).

Of particular interest have been the effects of social context on stress physiology, especially the activity of the hypothalamic-pituitary-adrenal axis (HPA), one of the major stress-sensitive systems in the body, and its major hormonal product, cortisol. There are a number of reasons for this focus. First, the HPA axis is very sensitive to social, emotional and psychological events, including exposure to environmental stressors as well as to social support systems. Second, the activation of the HPA axis has implications for a wide variety of other physiological systems crucial to short-term functioning as well as long-term health outcomes. Finally, cortisol may be non-invasively and reliably measured on a repeated basis in naturalistic settings, as it can be measured in small amounts of human saliva (Kirshbaum & Hellhammer 1989; Kirshbaum & Hellhammer 1994).

After describing some background material on physiological stress and particularly cortisol activity, this chapter will report data relating momentary events and emotions in the everyday lives of working mothers and fathers to the activity of this physiological system, helping moving us towards a better understanding of how daily experiences "get under the skin", with potential implications for performance as well as emotional and physical health.

Cortisol Reactivity to Stressful Events

When an individual encounters a stressful event (a stressor), a variety of physiological changes occur that are designed to assist the individual in dealing with the stressor (the stress response). The goal of these changes is to promote survival by activating the necessary attentional and energetic resources needed to contend with the immediate threat, and suppressing physiological activity that is irrelevant to that goal.

There are two major physiological systems involved in the stress response: the sympathetic-adrenal-medullary (SAM) system and the HPA axis. The SAM system is the rapid-response component of stress-system activation, causing a nearly immediate release of epinephrine (adrenalin) and norepinephrine, and the initial increases in vigilance and arousal that accompany the perception of a potential threat (Johnson, Kamilaris, Chrousos & Gold 1992; Sapolsky 1998). Measurement of sympathetic activity requires the collection of blood, urine, or cardiovascular data, and activation of this system is less specific to negative emotional events than is the HPA axis, making it more difficult to measure and interpret this component of physiological stress activation in naturalistic research (Lovallo & Thomas 2000).

If evaluation of the threat suggests that it is warranted, the SAM response is reinforced and extended by the activity of the slower but longer acting HPA axis. A simplified model of the HPA component of the stress response is depicted in Figure 8.1.

INSERT FIGURE 8.1 ABOUT HERE

The HPA response to stress begins in the brain with the release of corticotropin-releasing hormone (CRH) from the hypothalamus, which stimulates the pituitary gland to release adrenocorticotropin (ACTH) into general circulation. ACTH in turn stimulates the release of cortisol from the adrenal cortex into the bloodstream. Most of this cortisol (95%) is immediately bound to a corticosteroid binding globulin (CBG) and albumin, making it biologically inactive, while the rest remains active to have effects on tissues throughout the body and feedback effects on the brain (Kirschbaum & Hellhammer, 1989). Conveniently for investigators, about 20-30 minutes after the onset of the stressor, some of this unbound portion of cortisol is detectable in human saliva (Johnson et al 1992; Lovallo & Thomas 2000; Stansbury & Gunnar 1996). The signal to decrease or shut down further production of cortisol comes from negative feedback of cortisol to the brain, especially to receptors in the hippocampus, hypothalamus and pituitary, with high circulating levels of the hormone suppressing further release of CRH, ACTH and cortisol (Chrousos & Gold 1992; de Kloet 1991).

Short-Term Effects of Cortisol

Stress-related increases in cortisol have a number of short-term effects on the body. A major role of cortisol in the stress response is to increase available energy resources through increased gluconeogenesis (glucose production). Cortisol also helps to temporarily suppress the activity of systems that typically operate in the absence of threat, such as digestion, growth, and sexual behavior (Johnson et al 1992). Increases in cortisol have complex effects on immune functioning. Initially, cortisol promotes the mobilization of immune resources, but it also serves to contain and suppress the immune response (Sapolsky 1998). Cortisol has been shown to suppress the activity of inflammatory cytokines, thus helping to reduce or contain inflammatory responses to injury or other biological insult (Chrousos 1995; Miller, Cohen & Ritchey 2002). Cortisol and the central CRH component of the HPA response also influence cognitive processes such as memory and learning (Chrousos & Gold 1992; de Kloet 1991; Johnson et al 1992). While HPA activation increases alertness, vigilance to, and memory of threat-relevant stimuli, it impairs more complex and non-threat relevant cognitive processes. Experimentally increased levels of cortisol are associated with less effective processing of information and poorer memory for new information (Lupien, Gillan & Hauger 1999; Lupien & McEwen 1997). Recent evidence suggests that stress-induced changes in stress hormones may also modulate the type of neural memory system used to process and store information (Packard & Cahill 2001).

What Activates the HPA Axis?

A variety of factors activate the HPA axis, ranging from internal physical events, such as pain or rapid loss of blood pressure, to external threats to the individual, such as the presence of, or even anticipation of potential physical or psychological harm. The HPA axis is thought to be active when a threat is perceived to overwhelm perceived coping resources (Gunnar 1987). It is not simply the nature of the stressful event (such as its intensity, its duration or the frequency with which it has occurred) but also the individual's perception of their ability to cope with it that determines the extent to which physiological change occurs. Any factor which influences individuals' perceptions of themselves and their environments, including their past history, their current emotional and physical state, and the nature of their support systems, can influence the extent to which a cortisol reaction occurs. Thus, the cortisol levels resulting from a stress encounter are the result of multiple factors, including the nature of the stressor, the characteristics of the individual, and the effectiveness of their coping resources. This responsiveness of the HPA axis to differences in individual and social coping resources makes it an especially interesting physiological system for social scientists to study.

Sex Differences in Stress Reactivity

There is some evidence to suggest that the HPA response to stress is larger in men than in women (Lovallo & Thomas 2000). While it is possible that this difference is due to differential evaluation of their environments, recent theorists have suggested that physiological differences between men's and women's stress systems play a role. Taylor, Klein, Lewis, Gruenewald, Gurung and Updegraff (2000) have proposed that in women, levels of oxytocin, in interaction with estrogen, may reduce the "fight-or-flight" response typically associated with stress in men, replacing it with a "tend-or-befriend" response. This "tend-or-befriend" response encourages women to care for rather than abandon their offspring in times of stress, and to develop support networks of other females who may help to protect both offspring and mother. The authors argue that this strategy would have held a clear evolutionary advantage for women, in that it maximizes the chances of survival of their offspring and thus the opportunity to pass on their genes to the next generation. For men, unencumbered by the daily care of offspring, the SAM and HPA mediated "fight or flight" strategy remains the most effective approach.

Basal Cortisol Activity

In addition to increasing in response to stressors, cortisol exhibits a regular diurnal pattern. That is, cortisol levels are strongly dependent on time of day. In adults, cortisol levels are typically highest in the morning in the hour after waking, dropping off rapidly in the first few hours after waking, then continuing to drop more slowly across the day, reaching a low point or nadir around midnight (Kirschbaum & Hellhammer 1989; Weitzman, Fukushima, Nogeire, Roffwarg, Gallagher & Hellman 1971). There is in fact a pronounced increase in cortisol levels in response to awakening, with levels 30 to 45 minutes after waking being substantially higher than those measured immediately after opening ones eyes in the morning (Pruessner et al 1997). This response appears to be independent of mode of awakening (spontaneous vs. alarm) and time of awakening (regular wake time vs. being woken in the night) (Hucklebridge, Clow, Rahman & Evans 2000). The diurnal cortisol pattern is established early in life, first emerging at about three months of age (Price, Close & Fielding 1983). This diurnal pattern is a crucial factor to consider when designing studies and analyzing cortisol data.

Individual differences in cortisol diurnal rhythms are also a variable of interest in research (Adam & Gunnar 2001; Smyth et al 1997), with researchers attempting to identify social-contextual, personality and mental and physical health factors associated with different daily patterns of cortisol. Measures examined have included differences in the average and total daily levels of cortisol as well as the degree of change in cortisol levels from morning to evening (the steepness or slope of the cortisol curve). Chronically elevated, chronically suppressed average cortisol levels, as well as flattened diurnal cortisol curves have all been considered to be dysfunctional patterns of cortisol activity (Chrousos & Gold 1992; Gunnar & Vasquez 2001; Heim, Ehlert & Helhammer 2000).

In prior research, I found that approximately 72% of the variation in cortisol levels across the whole day was explained by time of day in a sample of adult women (Adam & Gunnar 2001). At any one time point in the day, some of the variance in cortisol levels will be due to the typical basal or "trait" levels of cortisol expected at that time of day, while some of the variance will be due to time-varying or "state" factors (Kirschbaum, Steyer, Patalla, Schwenkmezger & Hellhammer 1990; Shirtcliff, Granger, Booth & Johnson 2002). One estimate of the trait vs. state contributions to individuals' morning cortisol levels found that approximately 24% to 36% of variation in morning cortisol levels was due to stable or trait factors, about 62 to 74% was due to state factors, and the rest was due to measurement error (Shirtcliff, Granger, Booth & Johnson 2002). Thus, although the total variability in cortisol levels across the whole day is to a large part explained by the basal or diurnal cortisol rhythm, at each time point in the day considerable variability remains to be explained by situational factors.

Cortisol and Emotional and Physical Health

Individual differences in cortisol activity are associated with a variety of emotional and physical health problems (Chrousos & Gold 1992; Heim, Ehlert & Helhammer 2000). Major depression has been consistently associated with higher than average daily cortisol levels in adults (Chrousos & Gold 1992). In addition, a variety of physical disorders have been associated with lower cortisol levels (Heim, Ehlert & Helhammer 2000) and a loss or flattening of the diurnal cortisol rhythm, including fibromyalgia (Crofford, et al 1994; McCain & Tilbe 1989), chronic fatigue syndrome (MacHale, Cavanagh, Bennie, Carroll, Goodwin & Lawrie 1998) and severe rheumatoid arthritis (Neeck, Federlin, Graef, Rusch & Schmidt 1990). Flattened daily cortisol curves have also been found in adults with insecure attachment relationships and less effective marital functioning (Adam & Gunnar 2001), and in children who have experienced maltreated and orphans who have suffered severe maternal deprivation (Gunnar & Vasquez 2001).

Internalizing problems in children and adolescents have been associated with increases in cortisol reactivity to stressful events (Granger, Weisz, McCracken, Ikeda & Douglas 1996; Smider et al, 2002). Externalizing problems, however, have been related to low levels of basal cortisol (Gunnar & Vasquez 2001; Shirtcliff, Granger, Booth & Johnson 2002) and dampened reactivity to stressful events (Klimes-Dougan, Hastings, Granger, Usher & Zahn-Waxler 2001; Smider et al 2002).

Recently, researchers have started to investigate whether maladaptive patterns of cortisol activity (both basal cortisol and cortisol reactivity) might have emerged over time from the normal functioning of the stress response system gone awry. While in the short term, activation of the HPA and other physiological stress systems may be adaptive, over the long term, frequent or chronic stress system activation can be harmful. For example, evidence from animal models has demonstrated that chronic elevations in glucocorticoids may cause first temporary alterations and then permanent damage to the neurons in the hippocampus involved in the negative feedback regulation of the HPA axis. This in turn causes further elevations in basal glucorticoid levels, and further hippocampal damage. As the hippocampus is involved in the formation of certain types of memories, this "glucocorticoid cascade" model has been used to explain some of the cognitive deficits associated with aging (Sapolsky, Krey & McEwen 1986).

In the "allostatic load" model (McEwen 1998; Schulkin, McEwen & Gold 1994), when physiological stress activation (called allostasis) is too frequent or chronic, it is thought to result over time in harmful wear and tear on the body (called "allostatic load").

Chronic underactivity of stress systems may also cause allostatic load, as a result of harmful overcompensation by the systems typically suppressed or contained by stress hormones (Schulkin, McEwen & Gold 1994). There have been relatively few empirical tests of the allostatic load model in humans. In one such study, Seeman, Singer, Ryff, Love and Levy-Storms (2002) related cumulative exposure to social stress to multiple indicators of allostatic load. Individuals who reported more positive relationship histories and more positive current social supports had fewer current indicators of allostatic load, such as high blood pressure, a higher bad to good cholesterol ratio, a higher waist-to-hip ratio, and higher basal levels of cortisol, epinephrine and norepinephrine. In the Seeman et al (2002) research, it was assumed that the individuals with less positive relationship histories had experienced more frequent stress reactivity, which in turn contributed to "allostatic load". The actual events contributing to and instances of stress reactivity were not measured. The current project attempts to actually identify moments of stress system activity in the everyday lives of parents that may contribute over time to allostatic load.

Cortisol and Everyday Experience.

The vast majority of prior studies examining cortisol reactions to emotions and events have taken place in a laboratory-based setting. Laboratory-based studies have the advantage of control – it is possible to observe cortisol activity in a consistent setting and to expose all individuals to the same stressful task. Laboratory based stressors may not, however, be equally stressful to all individuals or as potent or personally meaningful as the stressors encountered in daily life. In addition, it is hard to interpret pre-task cortisol levels as individuals may have increases in cortisol in anticipation of their participation in the experiment, or changes in cortisol in response to traveling to the lab. These problems may account for the relatively inconsistent results that have emerged from this type of research (Gunnar 2001; Nicolson 1992; van Eck, Nicolson, Berkhof & Sulon 1996b).

Repeated testing of cortisol levels in everyday settings, in conjunction with measurement of real-life events and moods, provides a solution to these problems. These procedures provide minimal disruption of everyday routines, and measure events that are relevant to participants' lives and therefore potentially more psychologically meaningful (de Vries 1992). In pairing cortisol levels with randomly selected events and emotions across the day, it is possible to identify factors associated with stress hormone activity which may turn out to be quite different than the limited range of stressors typically utilized in the lab setting. Studies of this nature may help us to uncover the types of daily events that, according to the allostatic load model, may over time contribute to the development of stress-related disorders, and also to identify how stress reactions may be reduced or buffered by aspects of the person or their situation.

Relatively few studies of cortisol reactivity to everyday events have been conducted. Nicolson (1992) studied three samples of college students undergoing a series of typical stressors such as examinations and drivers license examinations. She reported average cortisol increases in anticipation of each of these events, as well as associations between cortisol levels and measures of participants' positive and negative mood states. In another study, van Eck, Berkhof, Nicolson and Sulon (1996a) found that stressful daily events and psychological distress were associated with increased cortisol secretion, with events that were relatively long in duration having a larger effect and familiar events being associated with a lesser cortisol response than equally stressful events that were novel. Smyth, Ockenfels, Porter, Kirschbaum, Hellhammer and Stone (1998) found increases in cortisol in response to events reported as stressful, as well as greater negative affect associated with higher cortisol levels and greater positive affect associated with lower cortisol levels.

The present study extends that prior work on cortisol reactivity to daily events by breaking down activities and moods beyond the positive and negative emotion distinction that has been analyzed previously, including an examination of parents' feelings about and experiences of their activities at the time of the cortisol sample, and how parents' emotions and cortisol levels differ according to their context – being at home, at work, or in public. All analyses will also examine and control for the associations between cortisol activity and medical factors, and will examine sex differences, both of which have been neglected in much of the prior research.

I anticipate that both men and women will show higher levels of cortisol activity at moments when they are experiencing high levels of negative emotion, and lower cortisol levels when they are experience positive emotions. Given the Taylor et al (2000) hypothesis, I expect that cortisol reactivity to negative emotions will be greater for men. I hypothesize that parents will show lower cortisol levels when they are experiencing feelings of enjoyment, control, and mastery over their activities. Whether or not cortisol levels are lower or higher than expected at home, at work, or in public will depend on parents' emotional experiences of their activities in each of these contexts.

Method

Data Collection

The data for this study were collected as a follow-up to the Sloan Family Study, conducted by the Alfred P. Sloan Center on Parents, Children and Work at the University of Chicago (B. Schneider & L. Waite, Co-PI's). Parents of children who had already participated in the Sloan Family Study were contacted and asked if they would like to be part of an additional "Physical Stress Study", in which we would examine how the stresses of work and family life affected their "physical stress and health". Procedures were explained in detail to interested participants, who were mothers and fathers of kindergarten-aged or adolescent children from primarily middle to high income, two-parent, working families. One hundred and twelve parents (69 mothers, 43 fathers) choose to participate in the follow-up study.

The study involved participants completing a set of diary entries paired with saliva samples, in order to link momentary situations and experiences with their stress hormone levels at the time of the diary entry. Participants were asked to complete six diary-sample pairs across day from morning to evening for two days during the course of their everyday lives. Diary-sample pairs were provided in the morning immediately after waking, in the evening immediately before bedtime, and four times during the day when signaled by a specially programmed watch. The watch signals were semi-random – they occurred at randomly selected moments within evenly spaced intervals across the day. Participants were asked to provide each saliva sample 20 minutes after each diary entry, since it takes 20 to 30 minutes after the onset of an event for the associated cortisol levels to show up in saliva. In the case of the beeped samples, a beep sounded first to signal the diary collection time, then again to signal the associated saliva sample collection time.

The diary entries involved answering a set of questions about the current situation at the time the watch beeped, including reporting what they were doing, who they were with, how they felt about the current activity, and their current emotions at the time. This procedure, known as the experience sampling method (ESM), has been extensively validated in prior studies (Csikszentmihalyi & Larson 1987). Details of the diary questions utilized in the current study are described in more detail below.

The saliva sampling procedure was quick and easy – it involved chewing a stick of gum to stimulate saliva, then expelling the saliva through a small straw into a vial. Participants refrigerated the saliva samples as soon as possible, then sent them back to us by courier. Salivary cortisol levels have been found to be robust to variations in temperature and motion similar to those experienced in a trip through the postal system (Clements & Parker 1998). Cortisol levels were obtained from the saliva samples through assays performed by experienced technicians at a laboratory specializing in salivary biomarkers (Salimetrics, State College, PA). Samples were assayed in duplicate for salivary cortisol by enzyme immunoassay. The test used for this study requires only 25 μl of saliva (for each singlet determination), has a range of sensitivity from .007 to 1.8 μg/dl, and average intra- and inter-assay coefficients of variation less than 5% and 9% respectively. Method accuracy, determined by spike recovery, and linearity, determined by serial dilution are 105% and 95%. Salivary cortisol values obtained using this test are strongly positively correlated with serum cortisol values, $r(17) = .94$, $p < .0001$. Samples with pH levels below the acceptable range, such that cortisol values may be affected, are identified and flagged during the assay process. Duplicate cortisol results were averaged and average values were used in all analyses.

In addition to completing the ESM diary-sample pairs, each participant completed a health survey, in which they reported on a variety of health and lifestyle issues that might affect cortisol levels, such as medication use, consumption of caffeine and alcohol, use of nicotine, timing of menstrual cycle, pregnancy, presence of chronic illness, and their height and weight (from which body mass index was calculated). Participants were excluded from the analyses if they were actively physically ill at the time they completed the study, if they had a serious chronic health condition known to affect endocrine function, or were using corticosteroid-based medications for the treatment of asthma.

It was not feasible to eliminate all individuals with a minor ongoing health problem as this would have represented 66% of the individuals in the study and severely limited the representativeness of the sample. Only 44% of participants reported having no health problems, with 37% reporting one health problem, 14% reporting two health problems, and 6% reporting three health problems. The associations between each of the health variables and basal cortisol, as well as the associations between health variables and cortisol reactivity to daily events were tested in order to identify and control for the possible influence of these variables on the results. Where associations between health conditions and basal cortisol or cortisol reactivity to daily events were found, these variables were included as control variables in all analyses.

Of the 112 parents who completed the procedures, two participants' data were not used due to the presence of serious medical conditions, five were eliminated due to use of steroid-based asthma medications, and four other participants were eliminated as a result of extensive missing data, leaving a total of 101 participants (64 mothers, 37 fathers). The average number of ESM-cortisol pairs completed by these participants was 10.01 out of the requested 12 pairs. When the cortisol data were present, but occasional ESM values were missing, missing ESM values were replaced with each person's mean value for that variable. Less than 5% of the ESM data were replaced in this manner.

<u>ESM Questions and Data Reduction</u>.

As mentioned above, the ESM diaries contained a variety of questions including questions about participants': a) thoughts and feelings about the main activity they were engaged in at the time of the beep; b) current emotions or mood state at the time of the beep and c) where they were -- their location at the time of the beep.

The feelings about the main activity section included the following questions, which were answered on a four-point scale ranging from Not at all to Very much: Did you enjoy what you were doing? Was this activity interesting? How well were you concentrating? Were you living up to your own expectations? Did you feel in control of the situation? Did the situation allow you to be involved or to act? Did you have the abilities to deal with the situation? Was the activity important to you? Were others expecting a lot from you? Were you succeeding at what you were doing? Did you wish you were doing something else? Did you feel good about yourself?

The current emotion or mood state section asked participants how they were feeling at the time of the beep. Mood states were rate on four-point unipolar scales ranging from Not at all to Very much, including Cheerful, Lonely, Nervous, Cooperative, Angry, Responsible, Frustrated, Competitive, Strained, Worried, Caring, Irritated, Relaxed, Stressed, Proud, Friendly, Hardworking and Productive.

In order to reduce the number of variables used in analyses and to reduce the possibility of Type 1 error, principal component analyses (with a varimax rotation) were performed on each set of variable[1]. When variables load on the same factor, this is an indication that they tend to co-occur – being experienced by the same individuals at the same point in time, rather than being experienced independently of one another. For the “Feelings about Activity” variables, 3 factors emerged, including an: “Enjoyment” factor, which was high on enjoyment of the activity and interest in the activity, and low on wishing you were doing something else; a “Mastery” factor, which was high on control of the situation, ability to deal with the situation, and perceived success; and an

"Involvement" factor, which was high on others expecting a lot from the respondent, degree of concentration, importance of the activity to the respondent, and the situation allowing the respondent to be involved or to act. The analysis of the "Mood State" variables also revealed 3 factors, including: a "Negative-Stress" factor which was high stressed, worried, strained, irritated, nervous, lonely and angry; a "Positive-Social" factor, on which cheerful, cooperative, proud, friendly and caring loaded highly, and a "Positive-Productive" factor, on which responsible, hardworking, and productive loaded highly.

Each participants' location at the time of the beep was answered in an open-ended format and classified into three categories: at home, at work, or in a public setting. We also categorized the degree of physical activity that was involved in the activity, on a four point scale ranging from "Very Sedentary" to "Very Physical", to test whether the degree of physical exertion involved in the activity may be contributing to cortisol levels.

<u>Data Analysis</u>

The first step in analyzing the data was to examine the cortisol values across the day for each participant. Cortisol values were expected to be high in the morning and decline across the day until evening. But not all patterns of cortisol change across the day will be identical, and within any one person's data some cortisol values will be higher or lower would be expected at that time of the day for that person. We can therefore ask the following set of questions.

1) How do momentary emotions and feelings about activities relate to cortisol levels, after taking into account the influence of the time of day and health-related variables on cortisol? Are these patterns of association different for men and women? These represent the central questions of the study, with the rest of the questions being elaborations of this central concern.

2) In which of the primary contexts of parents lives - at home, at work, or in public, are each of the mood states and feelings about activities experienced most strongly?

3) Are cortisol levels higher than lower than expected at that time of day when parents are at home, at work, or in public? Are these differences accounted for by the mood states and feelings about activities that were typical of each setting?

The first set of questions was answered using Hierarchical Linear Modeling (HLM) Growth Curve analysis (Bryk & Raudenbusch 1992). In a Level 1 HLM model, a curve was plotted through the cortisol values across the day for each individual, which provided estimates of the cortisol values expected at each time of day for each person. Deviations from those expected values were predicted from the mood states and feelings about activities experienced at the time of each beep, by adding these variables to the Level 1 model including the time of day variables. Whether or not these patterns were modified by the health variables or the sex of the parent was tested in a Level 2 HLM model.

The second set of questions, regarding associations between momentary emotions and feelings about activities and location (home, work, public) at the time of each beep were examined using 2-way ANOVAs, with location as within-subject factor and sex as a between-subject factor. When main effects or interaction terms were significant, results were interpreted further by conducting a series of post-hoc contrasts comparing the means for the different locations and/or for mothers vs. fathers.

The third set of questions, regarding whether or not cortisol levels were associated with the location of the parent at the time of the beep, and whether those associations were mediated by parents' moods and feelings about activities, were addressed in another HLM model, with the momentary location and emotion data entered in two separate steps at Level 1, and sex of parent and the health control variables entered at Level 2.

Results

Cortisol Patterns across the Day for Mothers and Fathers.

As seen in Figure 8.2, the cortisol data for the parents in the study did show the expected strong diurnal rhythm in cortisol levels – levels are highest in the morning, drop most rapidly in the morning, then continue to decline to near zero values at bedtime[2].

INSERT FIGURE 8.2 ABOUT HERE

Change in cortisol levels across the day were modeled for each individual separately in a Level 1 HLM model. As this effect was not linear, several curvilinear models were tested. The best fit was obtained by a 2nd degree polynomial function, including both linear (time) and quadratic (time of day squared) terms for time of day. Time of day values were expressed as deviations from their mean (centered at their mean) in order to reduce possible multicollinearity between the linear and quadratic terms (see Neter, Wasserman and Kutner, 1990, pp. 315-316). Using this model, time of day accounted for 67% of the variation in participants' cortisol levels.

Health Control Variables

Even when individuals using steroid-based medications were removed from the sample, having an asthma diagnosis was associated with a slight flattening of the daily cortisol curve (b=.078, t=2.51, p=.012). The presence of an asthma diagnosis and having a higher body mass index (BMI) were shown to modify the strength of the relationships between positive and negative emotion and cortisol (details below). I therefore included both asthma diagnosis and BMI as control variables in all analyses. Exclusion of these variables did not, however, meaningfully alter the nature of the other study results.

Momentary Emotions and Cortisol Levels

The average associations between ESM mood variables and momentary cortisol levels, controlling for time and day and health variables, are presented in Figure 8.3.

INSERT FIGURE 8.3 ABOUT HERE

The bars represent how much higher or lower the cortisol level is than the expected level at that time of day, for each one standard deviation change in each emotional state factor. A visual inspection of the figure suggests that being in a negative emotional state is associated with higher momentary cortisol levels, while being in a positive emotional state is associated with lower momentary cortisol levels. The HLM analysis (see Table 8.1 in the Appendix), confirms that higher levels on the negative-stress emotion factor are significantly associated with higher cortisol levels than expected at that time of day (b=.014, t=2.12, p=.033). At the average cortisol level of the day, (approximately .25μg/dl), this represents a relatively modest 6% increase in cortisol levels per standard deviation increase in negative emotion. The range of coefficients for the association between negative emotion and cortisol, however, was -.07 to .23. Certain individuals, therefore, experienced up to a 92% increase in cortisol for each standard deviation increase in negative emotion. Several factors explaining these individual differences in cortisol reactivity to negative emotion have been identified thus far in this study. The association between negative emotion and cortisol levels was significantly stronger for men than for women (b = .036, t = 2.26, p = .024 for the test of the difference between men's vs. women's coefficients), suggesting that men have significantly greater cortisol reactivity to negative emotion then women. Having an asthma diagnosis, however, was associated with a lesser degree of cortisol reactivity to negative emotion (b=-.021, t=-2.07, p=.038), as was having a higher body mass index (BMI; b=-.003, t=-3.87, p=.000).

Feeling higher levels of positive-social emotions, such as cheerful, friendly and caring (b=-.024, t=-3.55, p=.001) is associated, on average, with lower cortisol levels than expected at that time of day. At the average cortisol level of the day (.25) this represents a 10% average decrease in cortisol per standard deviation increase in positive-social emotion. The range of coefficients for positive-social emotion was -.29 to .02, such that some individuals experienced up to 108% lower cortisol levels for each one standard deviation increase in positive emotion.

Finally, lower cortisol levels were also experienced when individuals were feeling hardworking and productive (b=-.027, t=-3.98, p=.000). A one standard deviation increase on the positive-productive factor was associated, on average, with cortisol values being .027 ug/dl below the expected value for the time of day (11% decrease in cortisol). The range of coefficients for the association between the positive-productive factor and cortisol was -.21 to .02, such that some individuals experienced up to an 84% decrease in cortisol per standard deviation change in feeling hardworking and productive.

Because all three of the mood variables were entered in the HLM analysis simultaneously, the effects reported represent independent associations between these variables and cortisol levels. That is, the effects for positive-social emotion and feeling hardworking and productive are separate from, rather than simply the opposite of the negative emotion effect. Together, the three mood variables account for 16% of the remaining variability in cortisol levels after accounting for the effect of time of day.

Feelings about Activity and Cortisol Levels.

The associations between parents' feelings about their activities at the time of the beep and their cortisol levels are presented in Figure 8.4.

INSERT FIGURE 8.4 ABOUT HERE

Once again, it appears that positive states, in this case positive feelings about the current activity one is engaged in, are associated with significantly lower cortisol levels. Higher enjoyment of present activities is related to lower cortisol levels (b=-.013, t=-3.33, p=.001), with cortisol levels on average being 5% lower for every standard deviation increase in enjoyment of activities. The coefficients for this effect ranged from .01 to -.03, with effect sizes ranging from a +4% to –12% change in cortisol per standard deviation change in enjoyment of activities at the average cortisol level of the day.

Interestingly, there is also a significant negative association between higher feelings of involvement with activities and cortisol levels (b=-.017, t=-2.08, p=.038; range of betas from -.27 to .12). Thus, the average decrease in cortisol for every standard deviation increase in task involvement was 7%, although for some individuals cortisol levels were up to 108% lower for every standard deviation increase in task engagement at the average cortisol level of the day. Recall that the involvement variable incorporates a combination of challenge and high levels of concentration and engagement with the task. There was no effect of feelings of mastery or control over the activity on cortisol levels. No significant sex differences were found in the associations between feelings about daily activities and cortisol levels. Together, the feelings about activity variables account for 10% of the variation in cortisol levels remaining after controlling time of day. When both the mood state and feelings about activity variables are entered in the model, a total of 25% of the cortisol variation remaining after controlling for time of day is explained.

Associations between Location and Mood and Feelings About Activity Variables

Given the strong pattern of associations between parents' mood states, and their feelings about the activities they are engaged in, the next set of questions asks "when do they most experience these different moods and feelings"? An initial attempt to answer this question, relevant to the concerns of the Sloan Working Family study, involved comparing mothers' and fathers' mood states and their feelings about their activities a) at home b) at work c) in public. Parents' average levels on each of the emotion and mood state factors in each of these 3 settings were calculated and compared using 2-way ANOVAs, with location (home, work, public) as a within-subject factor and parent gender as a between-subject factor[3]. Using person-level data rather than the data for all the individual beeps is considered preferable in that it avoids the correlated error and exaggerated degrees of freedom that can be a problem with beep-level data. It also weights each individual equally rather than individuals completing more beeps having a greater influence in the analysis (Larson & Delespaul 1992). In addition, using a within-subjects' comparison ensures that the effect is not accounted for by between-subject differences on these variables. When overall ANOVA's were significant, post-hoc comparisons were made between the individual groups, and effect size statistics (Cohen's *d*) were calculated. Effect size statistics provide additional information beyond significance levels because they are not dependent on sample or cell sizes, and are therefore more comparable across studies. Cohen (1988) provided guidelines suggesting that a *d* of .2 can be considered small, .5 medium, and .8 or above to be a large effect size for social science research (but see also McCartney & Rosenthal, 2000, who suggest that Cohen's criteria may in some cases underestimate the importance of effects).

INSERT FIGURE 8.5 ABOUT HERE

As shown in Figure 8.5 and Table 8.3 (in Appendix), there are significant associations between location and parent mood state, for both the positive-productive factor [$F(2,103)=78.4$, $p=.000$], and the positive-social factor [$F(2,103)=25.6$, $p=.000$]. Post-hoc contrasts revealed that parents feel significantly more hardworking/productive at work than in public (*d*=.99) or at home (*d*=1.64), and more hardworking/productive in public than at home (*d*=.34). In addition they feel more positive-social in public settings than at either at work (*d*=.24) or at home (*d*=.69), and more positive-social at work than at home (*d*=.46).

There were also significant effects of gender on negative affect [F(1,104) = 6.4, p = .01] and significant interactions between parent gender and location in predicting negative affect [F(2,103)=5.61, p=.005]. Post-hoc contrasts revealed that men experienced higher levels of negative emotion than women across all settings (*d*=.51), but that women experienced higher levels of negative affect at work than at home (*d*=.34) or in public (*d*=.45), whereas there were no significant differences in negative affect by location for men (although they experienced their highest levels when in public)[4].

INSERT FIGURE 8.6 ABOUT HERE

In terms of their feelings about activities, there were significant main effects of location for mastery [F(2, 103)=7.1, p=.001] and involvement [F(1,103)=75.0, p=.000] (see Table 8.3 in Appendix). Higher levels of mastery were experienced at work and in public than at home (*d*=.45 and *d*=.28 respectively). Levels of involvement were higher at work than in both public settings (*d*=.67) and at home (*d*=1.44), and higher in public than at home (*d*=.77). On average, women experienced higher enjoyment of activities than men [F(1,104)=5.2, p=.03; *d*=.45], but there was also an interaction between gender and location in predicting enjoyment [F(2,103)=5.0, p=.009]. While there were no differences between work, public and home for enjoyment for men, women experienced significantly higher levels of enjoyment of activities in public settings and at work than at home (*d*=.65 and *d*=.59 respectively).

Associations between Location and Parent Cortisol Levels.

The results of the HLM model predicting parents' cortisol levels from parent location at the time of the beep, controlling for time of day, are presented in Table 8.4. Dummy (0 1) variables for being in public and for being at work were entered in the Level 1 HLM model after the time of day variables (being at home was the excluded or comparison group). Given the fact that feeling hardworking and productive and high levels of enjoyment of and engagement in one's activities are strongly associated with lower cortisol, and parents report higher levels of these experiences in the work setting, it is not surprising that cortisol levels were found to be significantly lower than expected for that time of day when parents are at work (b=-.080, t=-5.89, p=.000; this corresponds to 32% lower than expected at the average/midday cortisol levels; see Table 8.4, Model 1 in the Appendix). Being in public was not associated with any systematic difference in cortisol levels (b=-.005, t=-.33, n.s). When the mood state and feelings about activity variables are included in the Level 1 Model after the location dummy variables, the association between being at work and cortisol levels is reduced by almost a third, but being at work remains a significant independent effect (b=-.055, t=-3.76, p=.001; 22% lower than expected at average/midday cortisol levels; see Table 8.4, Model 2 in Appendix). Thus, parents' mood states and feelings about their activities at the time they were beeped partially, but not fully mediate the association between being at work and cortisol levels. Although a variety of other characteristics of the individual and the workplace environment (such amount of control in the workplace, level of physical activity, level of income and of occupational prestige) were tested, no other factors mediating or moderating the size of this association were identified.

Discussion

Clearly, parents' momentary emotions and how they feel about their daily activities are related to their physiological state, in this case their levels of the stress-sensitive hormone cortisol. In this study, all three factors found for participants' moods and two out of three factors found to describe participants' feelings about their current activities in their typical daily lives were significantly related to their cortisol levels twenty minutes later. More specifically, controlling for time of day and medical factors, higher levels of a negative emotion factor were associated with higher levels of cortisol (an effect which was significantly stronger for men than for women), and higher levels of a positive-social emotion factor and a hardworking-productive factor were associated with lower levels of cortisol twenty minutes later. When examining parents' feelings about their main activities at the time of the beep, higher levels of an enjoyment factor, and higher levels on a challenge-engagement factor were both independently associated with lower levels of cortisol than expected at that time of day. Parents in this study experienced more feelings of being productive and higher levels of involvement with (for both mothers and fathers) and enjoyment of (for mothers only) their activities when they were at work than when they were at home. Cortisol levels were correspondingly lower when parents were in the work setting. Parent mood and feelings about activities at the time of the beep partially, but didn't fully mediate the association between being at work and cortisol levels.

Several medical variables were significantly related to either basal cortisol patterns or cortisol reactivity to momentary events. The presence of an asthma diagnosis was associated with flatter diurnal cortisol rhythms, even after individuals using steroid based medications were excluded. In addition, the presence of asthma was associated with lower cortisol reactivity to negative emotion. A dampened association between negative emotion and cortisol was also found in individuals with a greater body mass index (a measure of body weight per unit height).

Negative Emotion and Higher Momentary Cortisol

The association between negative emotion (such as stressed, strained, angry, worried) and higher cortisol is in accord with the few prior studies using a momentary methodology (Nicolson 1992; Smyth et al 1998; van Eck et al 1996a). Understanding factors in the everyday lives of families that contribute to higher cortisol levels is important, as noted above, because of the potential short-term negative effects of cortisol on functioning, and also because frequent or prolonged exposure to increased cortisol levels may have harmful long-term effects on health. The current results suggest that the momentary stresses of parents' daily working lives are indeed related to small increases in cortisol – the extent to which this momentary reactivity adds up over time to contribute to long-term health problems requires further study. In doing so, it will be important to identify which individuals are characterized by more frequent and/or more extreme cortisol responding to negative emotion, as there was considerable variability in the size (and even direction) of the association between negative emotion and cortisol levels.

In the current study, one such factor that was identified was gender - the positive association between negative emotion and cortisol was significantly larger for the men in the study compared to the women. This result provides some support for the theory put forward by Taylor et al (2000), which suggests that women's physiological response to stressors is different than men's. These authors suggest that the female stress response is characterized by a "tend and befriend" response rather than the "fight or flight" response which typically involves increased sympathetic and HPA activation, thus lower stress-related levels of cortisol would be expected.

Positive Emotion and Lower Cortisol

Some of the more novel findings of the current study involve the associations between positive-social and positive-productive moods and lower levels of cortisol. Positive-social moods involved feeling happy, cheerful, social, cooperative and caring, and positive-productive moods included responsible, hardworking and productive. The finding of positive-social emotions being related to lower cortisol to a certain extent fits with the Taylor et al (2000) idea of a social coping component to the stress response, but the fact that this association was not significantly stronger for women does not fit with their idea that this is a characteristically female response. The possibility that social relationships may be important in modulating cortisol activity for both men and women in their everyday lives deserves further attention in future research. In particular, with a larger sample size or larger number of beeps per person, further examination of who the person is with at the time of the beep, and the effect of the quality of the respondents' relationships with those individuals on cortisol could be a fruitful approach.

Productivity, Engagement and Enjoyment of Activities and Lower Cortisol

The findings of lower levels of cortisol when individuals were engaged in activities that they found to be enjoyable, and in response to activities with which they felt highly involved, active and engaged and had high levels of concentration are also novel. A similar association between engagement in activities and lower cortisol has been reported in one prior laboratory study (Frankenhauser 1979), however this question has not been previously examined or reported in naturalistic settings.

Although at first glance one might expect challenging involvement in activities to relate to higher cortisol levels, prior evidence suggests that cortisol does not increase in situations of successful effort, but rather under conditions where challenges are perceived to be beyond one's abilities to successfully cope with the situation (Kirschbaum & Hellhammer 1989). The concept of challenge being associated with positive emotional experience has been investigated in detail in Chikszentmihaliyi's (1988, 1990) theory of the psychological state of "flow". According this line of research, a positive emotional experience of "flow" occurs when individuals are faced with tasks that incorporate an appropriate balance between challenge and skills level, such that the task is neither boring (when challenge is too low or skill too high) or anxiety-provoking (when challenge is too low or skill too high). The current findings suggest the possibility that flow states may be accompanied by lower cortisol.

One implication of this finding is to make the point that daily challenges are not inevitably physiologically stressful[5], but may in fact make positive contributions to our psychological states and our to our physical well-being. Differentiating between the "good" stresses, that exercise and stretch our abilities but lead to reward and success, and the "bad" stresses, which threaten to challenge us beyond our coping abilities, resulting in frustration or too frequent or chronic activation of the HPA axis, may be an important distinction to make in future research (in our own lives). Just as a certain amount of cortisol is necessary for basic daily functioning, so a certain amount of challenge may be an important part of healthy living.

Mood States and Feelings About Activities in Different Contexts

This point is reinforced by the findings regarding parental mood states and their experiences of activities at home, in public, and at work. Although there were some complex interactions with gender, in general parents experienced their highest levels of feeling productive and involved in the work setting, along with high feelings of enjoyment and mastery of activities. Parent cortisol levels were also significantly lower in the work setting than would be expected given the time of day. The lower cortisol levels in this setting were partially but not fully accounted for by parents' emotions or feelings about their activities at the time of the beep. One possible reason for this is the fact that stress-induced cortisol levels do not decay very quickly (the estimate decay time for cortisol is about an hour to an hour and a half) such that the levels of cortisol at any one point in time may reflect cumulative experiences over the past hour rather than the emotional experience at that moment, such as that captured in each ESM diary report. Further research could explore alternative wordings of the ESM that ask individuals to reflect back over a larger period of time. With a larger sample size, research could also identify in more detail the particular work activities and conditions that are associated with the types of positive engagement and lower cortisol levels reported here.

Parents' reports of experiences at home in these data were characterized by lower levels of feeling positive-social emotions, feeling hard-working and productive, and lower levels of enjoyment, mastery, and engagement in activities. This effect may be partially accounted for by the fact that in order to properly capture the cortisol daily rhythm, cortisol samples and diary entries were required immediately after waking and immediately before bedtime, when they may be less alert and less positively engaged with family members. Indeed, parents feel significantly less social and productive, and have lower levels of enjoyment and involvement in activities during these waking and bedtime periods than at other times at home[6]. Future research should attempt to sample both on weekdays and weekends in order to sample a broader range of home-based experiences (although certainly these morning and late evening periods are a part of participants' daily experiences of their home lives).

<u>Which Comes First, The Emotion or the Hormone</u>?

The question of the direction of effect of cortisol and momentary experience is not definitively answered in the current study. One of the age-old debates in emotion theory is whether or not emotional experience causes a change in physiological state or whether the emotion is the experience of the physiological state. A similar directional question could be asked regarding the feelings about activity variables. Does a persons' engagement in activities cause a change in their levels of cortisol, or does their hormonal state influence their experience of and ability to engage in an activity? There is evidence in prior research for both of these arguments. There is a large body of experimental evidence showing that exposure to a stressful situation increases cortisol levels (Kischbaum & Hellhammer 1989), and one experimental study found that "confident task involvement" led to a drop in cortisol levels (Frankenhauser 1979, p. 136). There is also evidence, however, that experimentally increased cortisol levels can cause changes in immediate functioning, including impairments in cognitive and memory processes (Lupien, Gillan & Hauger 1999; Lupien & McEwen 1997).

Perhaps these variables are dynamically interacting over time, with experiences and activities altering our emotions and hormone levels, and hormone levels influencing our interpretation of our environments and either hindering or facilitating our engagement with activities. Future research of the sort described in this chapter, but with a greater number of data points per day, could use a time-lagged or sequential approach to gain more insight into these questions. The fact that the current study built in a lag of twenty minutes between the diary report and the measurement of cortisol lends some weight to the possibility that the cortisol level is a reflections of the prior emotional state, although without more frequent measurement no strong conclusions about these dynamics can be made. At the least, this study provides evidence that complex transactions between our activities, emotions, and hormones are an ongoing part of our everyday existence.

Associations between Asthma and Body Mass and Cortisol.

While a flattening of the cortisol diurnal rhythm has been previously reported for several other stress-related disorders (see Adam & Gunnar, 2001), the flattened cortisol rhythms found in the current study for asthma have not previously been reported. The finding of dampened cortisol reactivity to negative emotion in asthmatics is also novel. These results should be interpreted with caution, as they are based on only six people, but they are nonetheless of interest given the known anti-inflammatory properties of corticosteroids in the body. Perhaps lower morning cortisol levels and a weakened cortisol response to stress in asthmatics contribute to a weakened ability to contain the inflammatory response in the airways that is part of the asthmatic disorder. Miller, Cohen and Ritchey (2002) suggest that a reduced sensitivity of inflammatory cytokines to suppression by glucocorticoids may contribute to the etiology of disorders involving excessive inflammation. The current study suggests the possibility that reduced stress-induced levels of glucocorticoids may also play a role, at least for asthma.

The finding of decreased cortisol reactivity to negative emotion among individuals with higher body mass has also not been previously reported. One possible explanation for this could be a difference in the time course of cortisol reactivity, with a time delay to peak level in people with higher body mass, due to higher blood volume. Another possibility could be differential rates of absorption of cortisol by fatty tissue vs. muscle. Finally, reduced physiological responsiveness of the HPA to psychological events, CRH, or ACTH among individuals with higher BMI is also a possibility. Clearly, all of these interpretations are speculative, and further discussion of the significance of these health-related findings should await replication of these results.

Conclusion

This study represents just one window into the ongoing and complex interplay between our environments and our biology. It nonetheless provides evidence that the simultaneous examination of activities, emotions and physiology in families' everyday lives is a profitable approach that yields insights on how the events of our daily lives can "get under our skin". This research is in many ways a perfect example of the biosocial perspective, which views individual biology and health as embedded in, and interacting dynamically with, their social contexts. The fact that our social environments can influence us not just at the level of our thoughts and emotions, but also at the level of our biology and health, makes a powerful case for the importance of social science research. In the long run, information on how our daily experiences of social settings influence our physiology may provide insights on how to changes these environments to improve the emotional, cognitive, and physical well-being of parents and their children.

References

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

Booth, A., Carver, K. & Granger, D. (2000). Biosocial perspectives on the family. Journal of Marriage and the Family, 62, 1018-1034.

Bryk, A. S. & Raudenbush, S. W. (1992). Hierarchical Linear Models. Newbury Park, CA: Sage Publications.

Cacioppo, J., Bernston, G., Sheridan, J., McClintock, M. (2000). Multilevel integrative analyses of human behavior: Social neuroscience and the complementing nature of social and biological approaches. Psychological Bulletin, 126, 829-843.

Chikszentmihalyi, M. (1990). Flow: The Psychology of Optimal Experience. New York: Harper Collins.

Chikszentmihalyi, M. & Chikszentmihalyi, I. (1988). Optimal Experience: Psychological studies of flow in consciousness. Cambridge: Cambridge University Press.

Chikszentmihalyi, M. & Larson, R. (1987), Validity and reliability of the experience-sampling method. Journal of Nervous and Mental Disease, 175, 526-536.

Chrousos, G. P., Gold, P. W. (1992). The concepts of stress and stress system disorders. Journal of the American Medical Association, 267, 1244-1252.

Clements, A. D. and Parker, R. C. (1998). The relationship between salivary cortisol concentrations in frozen versus mailed samples. Psychoneuroendocrinology, 23, 613-616.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Lawrence Earlbaum Associates.

Crofford, L. J., Pillemer, S. R., Kalogeras, K. T., Cash, J. M., Michelson, D., Kling, M. A., Sternberg, E. M., Gold, P. M. & Wilder, R. L. (1994). Hypothalamic-pituitary-adrenal axis perturbations in patients with fibromyalgia. Arthritis and Rheumatism, 37, 1583-1592.

de Kloet, E. R. (1991). Brain corticosteroid receptor balance and homeostatic control. Frontiers in Neuroendocrinology, 12, 95-164

de Vries, M. W. (1992). The experience of psychopathology: Investigating mental disorders in their natural setting. Cambridge: Cambridge University Press.

Flinn, M. V. & England, B. G. (1995). Childhood stress and family environment. Current Anthropology, 36, 854-866.

Frankenhauser, M. (1979). Psychoendocrine approaches to the study of emotion as related to stress and coping. In H. E. How & R. A. D. Dienstbier (Eds.), Nebraska Symposium on Motivation 1978 (pp. 123-161). Lincoln: University of Nebraska Press.

Gunnar, M. R. (1987). Psychobiological studies of stress and coping: An introduction. Child Development, 58, 1403-1407.

Gunnar, M. (2001). The role of glucocorticoids in anxiety disorders: A critical analysis. In Vasey, M. W. & Dadds, M. R. (Eds). The developmental psychopathology of anxiety, pp. 143-159. Oxford: Oxford University Press.

Gunnar, M. R. & Vazquez, D. M. (2001). Low cortisol and a flattening of the expected daytime rhythm: Potential indices of risk in human development. Development and Psychopathology, 13, 515-538.

Granger, D. A., Weisz, J. R., McCracken, J. T. (1996). Reciprocal influences among adrenocortical activation, psychosocial processes, and the behavioral adjustment of clinic-referred children. Child Development, 67, 3250-3262.

Heim, C., Ehlert, U., Helhammer, D. (2000). The potential role of hypocortisolism in the pathophysiology of stress-related bodily disorders. Psychoneuroendocrinology, 25, 1-35.

Hucklebridge, F., Clow, A., Rahman, H. & Evans, P. (2000). The cortisol response to normal and nocturnal awakening. Journal of Pscyhophysiology, 14, 24-28.

Johnson, E. O., Karmilaris, T. C., Chrousos, G. P., & Gold, P. W. (1992). Mechanisms of stress: A dynamic overview. Neuroscience and biobehavioral reviews, 16, 115-130.

Kirschbaum, C., & Hellhammer, D. H. (1989). Salivary cortisol in psycho-biological research: An overview. Neuropsychobiology, 22, 150-169.

Kirschbaum, C., & Hellhammer, D. H. (1994). Salivary cortisol is psychoneuro-endocrine research: recent developments and applications. Psychoneuroendocrinology, 19, 313-333.

Kirschbaum, C., Steyer, R., Eid, M., Patalla, U., Schwenkmezger, P., & Hellhammer, D. H. (1990). Cortisol and behavior: 2. Application of a latent state-trait model to salivary cortisol. Psychoneuroendocrinology, 15(4), 297-307.

Klimes-Dougan, B., Hastings, P., Granger, D., Usher, B. A., Zahn-Waxler, C. (2001). Adrenocortical activity in at-risk and normally developing adolescents: Individual differences in salivary cortisol basal levels, diurnal variation, and responses to social challenges. Development and Psychopathology, 13, 695-719.

Larson, R., Delespaul, P. A. (1992). Analyzing Experience Sampling data: A guidebook for the perplexed. In deVries, Marten W. (Ed). (1992). The experience of psychopathology: Investigating mental disorders in their natural settings, pp. 58-78. Cambridge: Cambridge University Press.

Lovallo, W. R. & Thomas, T. L. (2000). Stress hormones in psychophysiological research. In J. Cacciopo, L. Tassinary, & G. Bernston, Handbook of Psychophysiology, 2nd Ed, pp. 342-367. Cambridge: Cambridge University Press.

Lupien, S. J. & McEwen, B. S. (1997). The acute affects of corticosteroids on cognition: integration of animal and human model studies. Brain Research Review, 24, 1-27.

Lupien, S. J., Gillin, C. J., Hauger, R. L. (1999). Working memory is more sensitive than declarative memory to the acute effects of corticosteroids: a dose-response study in humans. Behavioral Neuroscience, 113, 420-430.

McCain, G. A. & Tilbe, K. S. (1989). Diurnal hormone variation in fibromyalgia syndrome: a comparison with rheumatoid arthritis. Journal of Rheumatology, 19, 154-157.

McCartney, K. & Rosenthal, R. (2000). Effect size, practical importance and social policy for children. *Child Development, 71*, 173-180.

McEwen, B. S. (1998). Stress, adaptation and disease: Allostasis and allostatic load. Annals of the New York Academy of Sciences, 840, 33-44.

MacHale, S. M., Cavanagh, J. T. O., Bennie, J., Caroll, S., Goodwin, G. M., Lawrie, S. M. (1998). Diurnal variation of adrenocortical activity in chronic fatigue syndrome. Neuropsychobiology, 38, 213-217.

Miller, G. E., Cohen, S., Ritchey, A. K. (2002). Chronic psychological stress and the regulation of pro-inflammatory cytokines: A glucocorticoid-resistance model. Health Psychology, 21*,* *6*, 531-541.

Neeck, G., Federlin, K., Graef, V., Rusch, D. & Schmidt, K. L. (1990). Adrenal secretion of cortisol in patients with rheumatoid arthritis. The Journal of Rheumatology, 17, 24-29.

Neter, J., Wasserman, W. & Kutner, M. H. (1990). Applied linear statistical models: Regression, analysis of variance, and experimental designs. Boston: Irwin.

Nicolson, N. A. (1992). Stress, coping and cortisol dynamics in daily life. In M. W. deVries (ed.), The Experience of Psychopathology: Investigating Mental Disorders in their Natural Setting, pp. 219-232. Cambridge: Cambridge University Press.

Packard, M. G. & Cahill, L. (2001). Affective modulation of multiple memory systems. Current Opinion in Neurobiology, 11, 752-756.

Price, D. A., Close, G. C., Fielding, B. A. (1983). Age of appearance of circadian rhythm in salivary cortisol values in infancy. Archives of the Disabled Child, 58, 454-456.

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, 2539-2549.

Rosen, J. B. & Schulkin, J. (1998). From normal fear to pathological anxiety. Psychological Review, 105, 325-350.

Sapolsky, R. M. (1998). Immunity, stress and disease. In Why Zebras Don't Get Ulcers: An Updated Guide to Stress, Stress-Related Diseases, and Coping. New York: W. H. Freeman and Company.

Sapolosky, R., Krey, L., McEwen, B. (1986). The neuroendocrinology of stress and aging: The glucocorticoid cascade hypothesis. Endocrine Reviews, 7, 284-301.

Schulkin, J., McEwen, B., & Gold, P. (1994). Allostasis, amygdala, and anticipatory angst. Neuroscience and Behavioral Reviews, 18, 385-396.

Seeman, T. E., Singer, B. H., Ryff, C. D., Love, G. D. & Levy-Storms, L. (2002). Social relationships, gender, and allostatic load across two age cohorts. Psychosomatic Medicine, 64, 395-406.

Shirtcliff, E. A., Granger, D. A., Booth, A., Johnson, D. (2002). A latent-state trait model of salivary cortisol and atypical social behavior in normally developing youth. Manuscript submitted for publication.

Smider, N. A., Essex, M. J., Kalin, N. H., Buss, K. A., Klein, M. H., Davidson, R. J. & Goldsmith, H. H. (2002). Salivary cortisol as a predictor of socioemotional adjustment during Kindergarten: A prospective study. Child Development, 73, 75-92.

Smyth, J., Ockenfels, M. C., Gorin, A. A., Catley, D., Porter, L. S., Kirschbaum, C., Helhammer, D. H. & Stone, A. A. (1997). Individual differences in the diurnal cycle of cortisol. Psychoneuroendocrinology, 22, 89-105.

Smyth, J., Ockenfels, M. C., Porter, L., Kirschbaum, C., Helhammer, D. H. & Stone, A. A. (1998). Stressors and mood measured on a momentary basis are associated with salivary cortisol secretion. Psychoneuroendocrinology, 23, 353-370.

Stansbury, K. & Gunnar, M. R. (1996). Adrenocortical activity and emotion regulation. Monographs of the Society for Research in Child Development, 59, (2-3, Serial No. 240), 108-134.

Taylor, S. E., Klein, L. C., Lewis, B. P., Gruenewald, T. L., Gurung, R. A. R., & Updegraff, J. A. (2000). Biobehavioral responses to stress in females: Tend-and-befriend, not fight-or-flight. Psychological Review, 107, 411-429.

van Eck, M., Berkhof, H., Nicolson, N., & Sulon, J. (1996a). The effects of perceived stress, traits, mood states, and stressful daily events on salivary cortisol. Psychosomatic Medicine, 58, 447-458.

van Eck, M., Nicolson, N. A., Berkhof, H., & Sulon, J. (1996b). Individual differences in cortisol responses to a laboratory speech task and their relationship to responses to stressful daily events. Biological Psychology, 43, 69-84.

Weitzman, E. D., Fukushima, D., Nogeire, C., Roffwarg, H., Gallagher, T. F. & Hellman, L. (1971). Twenty-four hour pattern of episodic secretion of cortisol in normal subjects. Journal of Clinical Endocrinology, 33(14), 14-22.

Endnotes

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[1]Components were retained if they had an eigenvalue greater than 1, and the appropriate number of components was also confirmed through visual inspection of a scree plot.

[2]In order to reduce a positive skew in the cortisol data and the influence of outlying values, a windsorizing procedure was used in which cortisol values greater than 2 were replaced with values of 2. In addition, all HLM models are reported using robust standard errors that are robust to slight violations of normalcy. A log transformation of the raw cortisol values across the entire day was not performed because this would have influenced the accuracy of fit of the diurnal cortisol curves. Time-controlled residual cortisol values were not substantially skewed.

[3]The sample size is slightly larger for these analyses because the five individuals taking corticosteroid-based medications were not excluded for these comparisons, which relied purely on self-report data.

[4] The smaller sample size for men than women may be contributing to fact that fewer comparisons are found to be significant for men than women.

[5]There is however evidence, both experimental and naturalistic, that increases in catecholamines (epinephrine, norepinephrine) are typically associated with task-related effort). It is this distinction between challenge and threat that typically differentiates between the activity of the SAM system and the activity of the HPA.

[6]For positive-social emotion paired-sample $t(105)=6.66$, $p=.000$; for hardworking-productive $t(105)=6.14$, $p=.000$; for enjoyment of activities $t(105)=5.88$, $p=.000$, for involvement in activities, $t(105)=7.26$, $p=.000$.

Table 8.1 - Hierarchical Linear Model Predicting Parents' Cortisol Levels from Time of Day and Mood State Factors (N=101)

Fixed Effect	Coefficient	SE	df	t-value	p-value
Cortisol Intercept					
Intercept	.165	.009	97	17.98	.000
Sex	.278	.002	97	1.39	.165
Asthma	-.017	.026	97	-.659	.509
BMI	.000	.001	97	.334	.738
Time of Day					
Intercept	-.166	.009	97	-18.14	.000
Sex	.030	.021	97	1.44	.150
Asthma	.078	.031	97	2.51	.012
BMI	.000	.002	97	.360	.718
Time of Day^2					
Intercept	.094	.007	97	13.05	.000
Sex	-.018	.017	97	-1.05	.293
Asthma	-.031	.021	97	-1.49	.137
BMI	-.001	.001	97	-.087	.386
Negative-Stress					
Intercept	.014	.006	97	2.12	.033
Sex	.036	.016	97	2.26	.024
Asthma	-.021	.009	97	-2.07	.038
BMI	-.003	.000	97	-3.87	.000
Positive-Social					
Intercept	-.024	.007	97	-3.55	.001
Sex	-.007	.016	97	-.432	.665
Asthma	.009	.030	97	.307	.759
BMI	.000	.000	97	.397	.691
Positive-Productive					
Intercept	-.027	.007	97	-3.98	.000
Sex	-.025	.015	97	-1.58	.112
Asthma	.009	.021	97	.448	.654
BMI	.002	.001	97	1.81	.070

Table continued on next page……

Random Effect	Standard Deviation	Variance Component	df	Chi-squared	p-value
Intercept	.058	.003	90	126.87	.007
Time of Day	.081	.007	90	223.52	.000
Time of Day^2	.053	.003	90	145.60	.000
Negative-Stress	.036	.001	90	79.48	>.50
Positive-Social	.048	.002	90	119.59	.020
Positive-Productive	.037	.001	90	102.66	.171

Note. The time of day and mood state variables were entered as Level 1 (within person, repeated measures) variables and parent asthma, parent sex and parent body mass were entered as Level 2 (between-person, individual difference) control variables in the HLM model.

Table 8.2 - Hierarchical Linear Model Predicting Parents' Cortisol Levels from their Time of Day and Feelings about Activity Factors (N=101)

Fixed Effect	Coefficient	SE	df	t-value	p-value
Cortisol Intercept					
Intercept	.155	.009	97	17.86	.000
Sex	.004	.019	97	.210	.834
Asthma	-.007	.030	97	-.232	.817
BMI	.002	.001	97	1.05	.296
Time of Day					
Intercept	-.163	.009	97	-18.54	.000
Sex	.019	.020	97	.920	.358
Asthma	-.069	.024	97	2.91	.004
BMI	.000	.001	97	.259	.796
Time of Day^2					
Intercept	.101	.008	97	12.32	.000
Sex	.001	.019	97	.039	.969
Asthma	-.025	.017	97	-1.47	.141
BMI	.002	.001	97	1.98	.048
Enjoyment					
Intercept	-.013	.004	97	-3.33	.001
Sex	.013	.010	97	1.43	.154
Asthma	.001	.010	97	.357	.721
BMI	.001	.000	97	1.78	.074
Mastery					
Intercept	-.007	.006	97	-1.15	.251
Sex	.011	.013	97	.848	.397
Asthma	.014	.017	97	.781	.435
BMI	.002	.001	97	1.98	.048
Involvement					
Intercept	-.017	.008	97	-2.08	.038
Sex	-.000	.019	97	-.009	.993
Asthma	.022	.013	97	1.67	.095
BMI	.001	.002	97	.712	.477

Table continued on next page…..

Random Effect	Standard Deviation	Variance Component	df	Chi-squared	p-value
Intercept	.047	.002	92	92.94	>.50
Time of Day	.072	.005	92	205.49	.000
Time of Day^2	.059	.003	92	164.49	.000
Enjoyment	.004	000	92	69.05	>.50
Mastery	.022	.000	92	100.49	.256
Involvement	.059	.003	92	97.43	.329

Note. The time of day and feelings about activity variables were entered as Level 1 (within person, repeated measures) variables and parent asthma, parent sex and parent body mass were entered as Level 2 (between-person, individual difference) variables in the HLM model.

Table 8.3 - Associations between Parents' Emotions, Feelings about Activities and Location by Parent Gender, Controlling for Time of Day

	Location at Time of Beep				
ESM Variable	Home	Public	Work	F	Contrasts[a]
All Parents					
Negative-Stressed	-.05 (.06)	.02 (.07)	.03 (.06)	1.0	
Positive-Social	-.14 (.07)	.36 (.07)	.19 (.07)	25.6***	P>W>H
Positive-Productive	-.14 (.05)	.07 (.07)	.69 (.05)	78.4***	W>P>H
Enjoyment	-.07 (.06)	.13 (.08)	.08 (.05)	4.5**	P, W>H
Mastery	-.07 (.07)	.12 (.06)	.21 (.05)	7.1***	P, W>H
Involvement	-.22 (.06)	.22 (.06)	.60 (.05)	75.0***	W>P>H
Mothers					
Negative-Stressed	-.17 (.08)	-.24 (.08)	.05 (.08)	5.0**	W>H, P
Positive-Social	-.20 (.09)	.45 (.08)	.27 (.08)		
Positive-Productive	.02 (.07)	.09 (.08)	.74 (.06)		
Enjoyment	-.10 (.07)	.32 (.09)	.21 (.06)	15.4***	P, W>H
Mastery	-.02 (.09)	.18 (.08)	.13 (.06)		
Involvement	-.17 (.07)	.24 (.08)	.58 (.06)		
Fathers					
Negative-Stressed	.06 (.10)	.28 (.11)	.00 (.10)	.17	n.s.
Positive-Social	-.08 (.12)	.26 (.11)	.11 (.10)		
Positive-Productive	-.29 (.09)	.04 (.11)	.63 (.08)		
Enjoyment	-.05 (.08)	-.05 (.11)	-.05 (.08)	.00	n.s.
Mastery	-.12 (.11)	.06 (.10)	.29 (.08)		
Involvement	-.27 (.09)	.20 (.10)	.62 (.08)		

*$p<.05$ **$p<.01$ ***$p<.005$
Note. Values outside parentheses are means, inside are standard errors. H=home, P=public, W=work
Note. DF's for All Parents ANOVA's are (2,103); for Mother and Father ANOVA's are (1,104)
[a]Contrasts are provided for All Parents when a significant main effect is present, and separately for mothers and fathers in the case of a significant interaction. Contrasts are paired sample t-tests, presented when significant at $p<.05$ or less.

Table 8.4 – Associations between location and cortisol controlling for time of day and health variables (Model 1) as well as mood state and feelings about activity variables (Model 2).

Model 1

Fixed Effect	Coefficient	SE	df	t-value	p-value
In Public	-.005	.016	97	-.331	.740
At Work	-.080	.014	97	-5.89	.000

Random Effect	Standard Deviation	Variance Component	df	Chi-squared	p-value
In Public	.076	.006	49	42.44	>.500
At Work	.063	.004	49	48.97	>.500

Model 2

Fixed Effect	Coefficient	SE	df	t-value	p-value
In Public	.006	.016	97	.361	.718
At Work	-.055	.015	97	-3.76	.000

Random Effect	Standard Deviation	Variance Component	df	Chi-squared	p-value
In Public	.080	.006	33	31.73	>.500
At Work	.070	.005	33	40.79	.165

Note. Coefficients for control variables not shown in order to preserve space. Home is the excluded (comparison) group.

Figure 8.1 - Schematic representation of the major components of the hypothalamic-pituitary-adrenal axis. Bold arrows represent excitatory effects, lighter dashed arrows show inhibitory effects. PVN, paraventricular nucleus of hypothalamus; CRH, corticotropin releasing hormone; ACTH, adrenocorticotropic hormone (corticotropin).

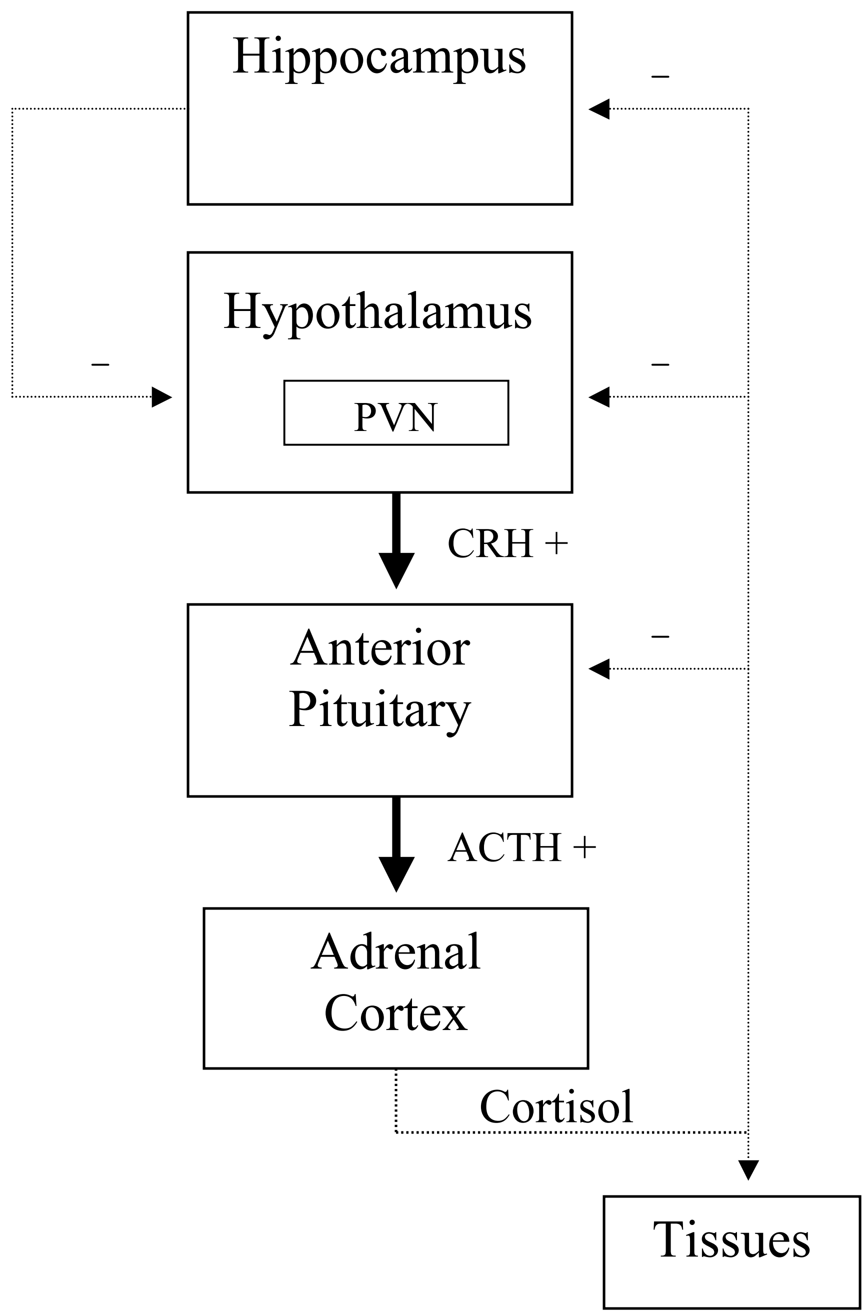

Table 8.2 - Observed cortisol values (in g/dl) for participants by time of day (on a 24 hr clock, includes both days of measurement).

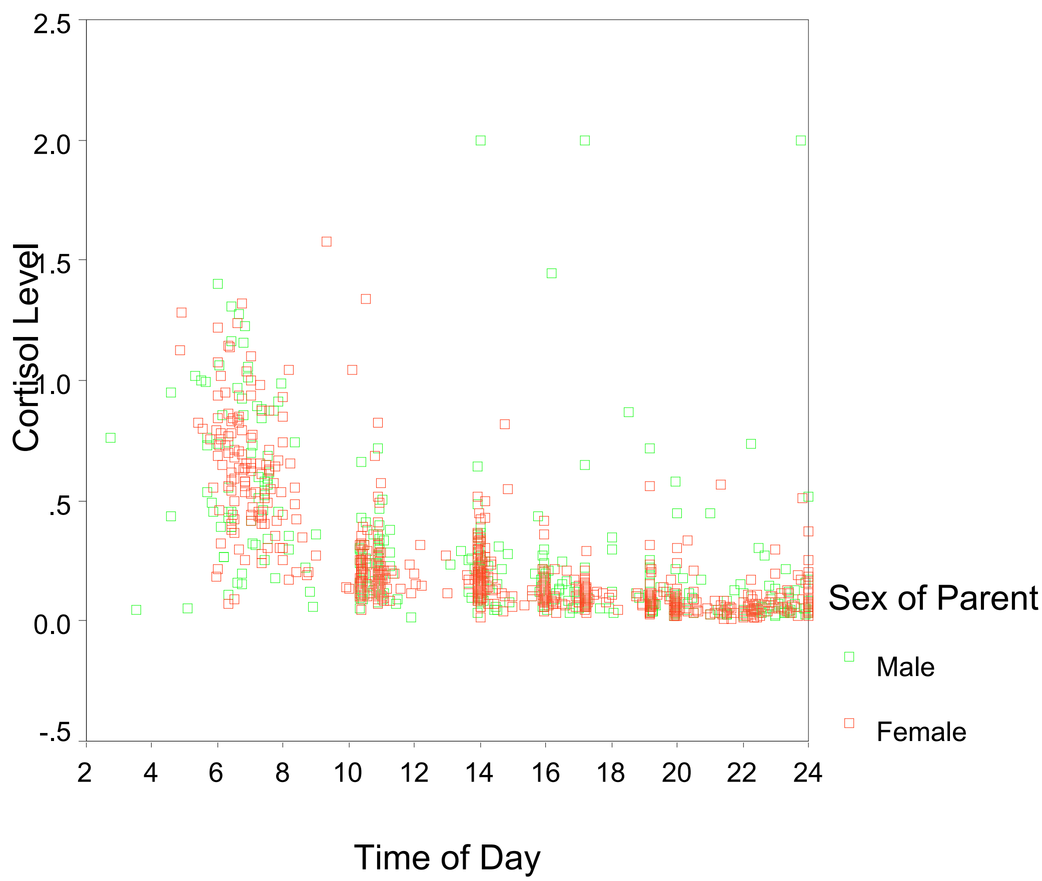

Figure 8.3 - Associations between ESM Mood State Factors and Cortisol Levels, Controlling for Time of Day.

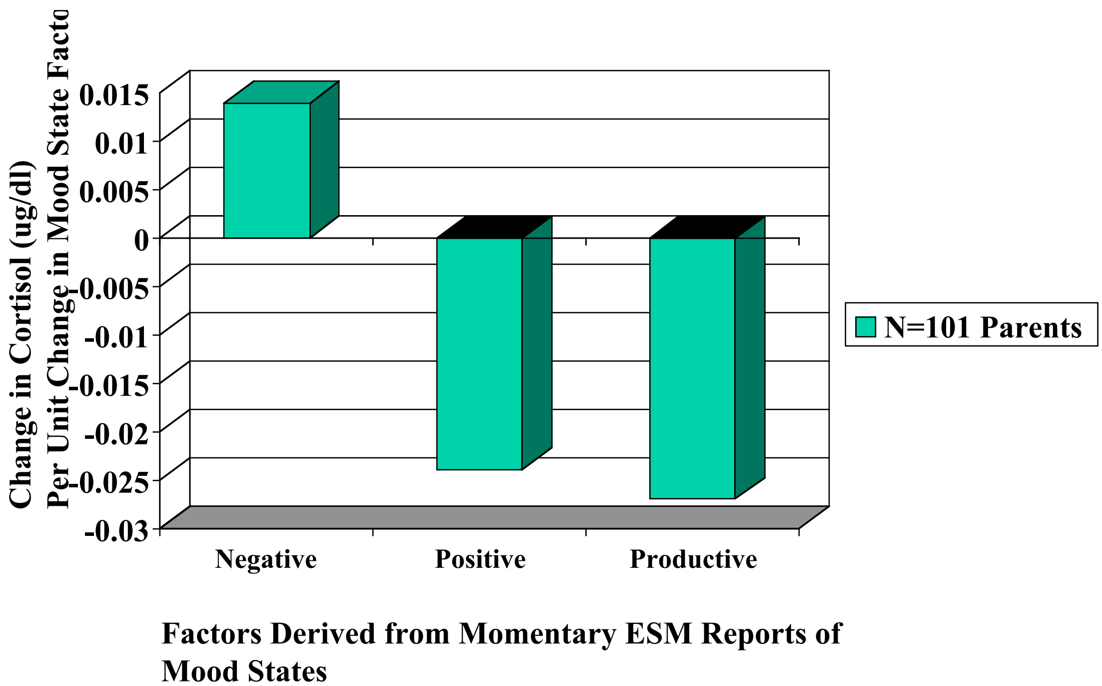

Figure 8.4 - Associations between ESM Feelings about Activities Factors and Cortisol Levels, Controlling for Time of Day.

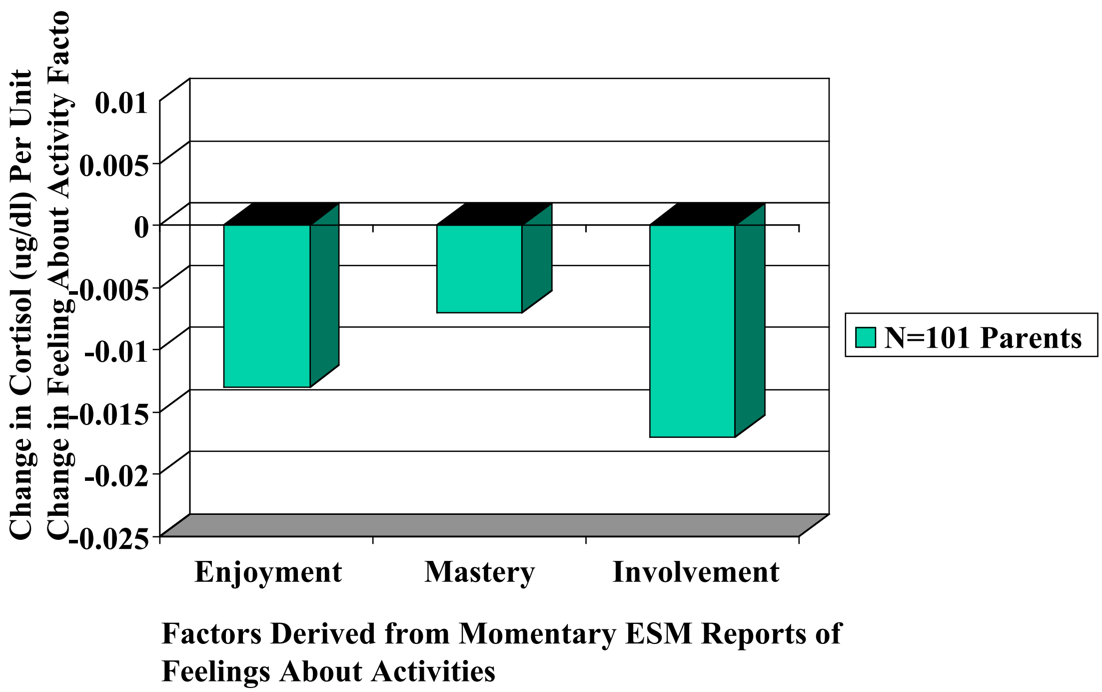

Figure 8.5 - Associations between ESM Reports of Parent Location (Home, Public, Work) and ESM Mood States.

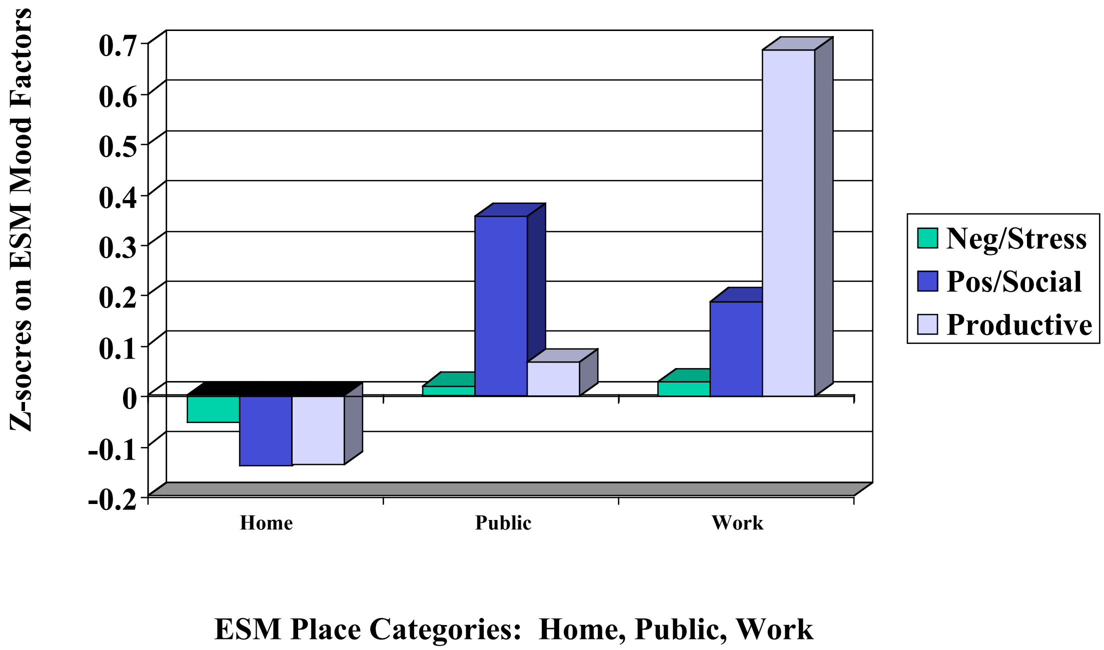

Figure 8.6 - Associations between ESM Reports of Parent Location (Home, Public, Work) and ESM Feelings about Activities.