The Pennsylvania State University

The Graduate School

College of Health and Human Development

EVENT-SPECIFIC CONTROL, SALIVARY CORTISOL, AND THE DAILY STRESS PROCESS

A Dissertation in

Human Development and Family Studies

by

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Submitted in Partial Fulfillment

of the Requirements

for the Degree of

Doctor of Philosophy

December 2009

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ABSTRACT

Perception of control over a specific stressful event plays an important role in the potential consequences of the stressor. Previous studies have documented the role of control in the stress process, but have often looked to trait measures of control that use an individual's global perceptions of how he or she affects the environment. In order to more accurately depict the daily stress process, perception of control over specific stressors is an important factor to include in conjunction with trait measure of control. The present research consists of three papers investigating event-specific control in the stress process and one potential biomarker of stress, salivary cortisol. Participants for all three studies come from the initial set of respondents participating in the second wave of the National Study of Daily Experiences (NSDE, N = 1,265). Participants for the NSDE come from a subsample of the National Survey of Midlife in the United States (MIDUS II).

The first paper examines daily variation in event-specific control (ESC) and how it is associated with trait measures of control. Results indicated more within-person variation in ESC than between-person variation. The second study is a methodological paper focused on salivary cortisol, a hormone known to be a specific physiological outcome of interest in the stress process. The discussion centers on challenges researchers face when collecting salivary cortisol in large field studies where researchers have no face-to-face interaction with participants and the resultant implications on the validity of measured salivary cortisol diurnal rhythm parameters. Study three combines findings from papers one and two to investigate the predictive nature of event-specific control on salivary cortisol. Results indicate that ESC is a significant predictor of the daily decline slope of salivary cortisol and that this relationship is moderated by age. These findings suggest event-specific perceptions of control play an integral role in the stress process.

Future studies investigating the stress process would benefit from the inclusion of ESC as a predictor and potential moderator of psychological and physiological outcomes.

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ACKNOWLEDGEMENTS

I would like to acknowledge the many people that helped me along the way as I pursued this Ph.D. First and foremost, to my advisor David Almeida, my sincerest gratitude and appreciation. Without your guidance over the past 5+ years, I have no idea how I would have gotten here. Our many conversations, whether we were talking about multi-level models or the newest Jack Johnson album, have made me realize how lucky I am to have you as a mentor and friend. I would also like to thank my entire dissertation committee for your contributions to this research and to my professional development.

It is important to acknowledge the financial support I have received from the National Institute of Aging via the Gerontology Training grant and for the support I received from the Department of Human Development and Family Studies. In addition, without the wonderful staff, specifically Mary Jo Spicer and Ann Shuey, no graduate student would ever make it through the program!

I would also like to thank my family for their continued guidance and support. You may not always have understood what I was doing throughout graduate school, but you all never forgot to tell me how proud you were on a regular basis. A very special thank you to *Illegal Grounds*, the coffee shop where I did most of my writing in Denver, CO. Without the continuous supply of caffeine, good music, and internet connection, I probably would have never finished writing.

Finally, to my amazing, beautiful, and intelligent wife, Tamie and our trio of trouble (Alex, Abbey, and Lola). Thank you for your love and support on a daily basis. Thank you for taking the girls on extra walks while I was writing. Thank you for always pushing me to be the best I could be.

DEDICATION

This dissertation is dedicated to David Goddess, my fifth grade teacher at Solis Cohen Elementary School in Philadelphia, Pennsylvania. On one of the last days of the school year he said, "Sean, you have the ability to get straight A's and do anything you ever want if you just put your mind to it." Throughout junior high and high school I would spend time calculating my grades, making sure I knew exactly what it took to get a "B". That was enough to make honor roll and keep my mom happy. It was not until my second year in college that the words of my fifth grade teacher finally sunk in and had an impact.

Mr. G., thank you for seeing something in me that it took me nearly 10 years to see in myself. You may have forgotten those words long ago, but on behalf of myself and many others, thank you for inspiring countless numbers of children to go for their dreams. This Ph.D. is for you.

CHAPTER I

OVERVIEW

Introduction

There is little doubt that stressful events have enormous implications on an individual's health. A very rich tradition of research has linked stressors to psychological (Wheaton, 1996; Lazarus, 1990), physical (Dohrenwend, 2000; Smyth & Stone, 2003), and physiological (Bolger & Zuckerman, 1995; McEwen, 2001; Dickerson & Kemeny 2004) well-being. Many characteristics of the individual play an important role in the potential impacts of a stressors including, but not limited to, age (Pearlin & Mullan, 1992; Chiriboga, 1989), socioeconomic status (Aldwin & Levinson, 2001), and gender (Kudielka et al 2004, Van Cauter et al, 1996). Consequences of stressors can even vary within an individual based on factors such as sleep patterns (Rao et al, 1996; Leproult et al, 1997; Friess et al, 2004), work environment (Hanson et al, 2000; Evans & Steptoe, 2001; Waye et al, 2002), and exercise (Rudolph & McAuley, 1995; Kirschbaum et al, 1996; Kamei, 2000; McGuigan et al, 2005). The amount of control an individual perceive in his general life, as well as the amount of control perceived in response to a specific stressors are important factors that buffer the consequences of stressors.

Perceived control refers to "expectations of being able to participate in making decisions and engaging in actions in order to obtain desirable consequences and avoid unfavorable ones" (Rodin, 1986; p. 6). The extent to which an individual feels he or she can dictate the outcome of a stressor has a great effect on the event's outcome and potential consequences. The purpose of this dissertation is to examine how two types of control buffer the effects of daily stressors. Specifically, trait control represents an individual's global perceptions about how he or she affects the environment across a multitude of domains. Alternatively, event-specific (or stressor-specific) control focuses directly on how perceptions of control over a stressor influence an individual's reactivity to the event. These two types of control, while very different, cannot be viewed as completely separate in their effects on the stress process.

The Stress Process

In order to accurately depict how perceptions of control may dictate the outcome of a stressful event, it may first be helpful to define what researchers mean by "stress". There is fairly wide agreement that there are two important components of the stress process, stressors and distress.

Stressors refer to "environmental demands which tax or exceed the adaptive capacity of the organism, resulting in psychological or biological changes that may place persons at risk for disease" (Cohen, Kessler, & Gordon, 1997; p. 3). In this sense, stressors are synonymous with demands or events that elicit some response. *Distress* indicates the biological or psychological consequence of the stressor.

Stressor exposure is the likelihood that an individual will experience a stressful event (Bolger & Zuckerman, 1995). Stressor exposure does not happen by chance or at random; rather, it is based on characteristics of individuals and their environments that serve as resilience or vulnerability factors (Almeida, 2005) such as age, gender, and socioeconomic status (SES). *Stressor reactivity* dictates the extent to which a person is likely to show emotional or physical reactions to stressful events (Bolger & Zuckerman, 1995; Almeida, 2005). That is, stressor reactivity refers to the level of response likely to be experienced by an individual following a stressful event. Stressor reactivity can refer to a variety of responses including emotional (i.e. anger or sadness), behavioral (i.e. smoking cigarettes, nail biting) and physiological (i.e. increases in hormones such as cortisol) or somatic symptoms (i.e. "butterflies" in the stomach, sweating, or goose bumps).

The “stress process”, first defined by Pearlin (1981; 1999), comprises a complex series of interactions that occur when an individual experiences a stressful situation. “Stress” in this sense, is not merely an event acting upon an individual. As the term “process” implies, stress represents many interrelated factors that may contribute to an outcome long before a stressful event takes place and whose effects may be manifested long after. For example, an individual with an overly demanding job may not recognize when her load became too taxing. Years later after developing an ulcer, she may not attribute the ailment to the chronic stressor but it more likely than not played a vital role.

The stress process also refers to the situations and events leading up to a stressor and the consequences following, some of which are immediate (i.e. within seconds) whereas others are not felt for days, months, or even years. Attempting to study the full process of stress would be a near impossible task for any one researcher as it comprises not only an event but also the personal characteristics of an individual that affect their exposure and responses to stress such as demographic information, proximal and distal environments, and individual resources available to cope with stress.

Scientists from many disciplines have been interested in this “stress process” long before Pearlin coined the term. In different fields, stress can infer quite different meanings. Sociologists have long been interested in stressors in the social sense, as in social equality, unemployment rates, national healthcare, and social disturbances (Pearlin, 2002; Dohrenwend, et al., 1998; Skodol, Dohrenwend, Link, & Shrout, 1990). The medical field examines stressors physiologically, as a noxious agent that sets off a chain reaction of events within the body as a response. Psychologists typically fall somewhere in the middle of these disciplines, concerned with stress from the standpoint of personal meaning. Some psychologists feel stressor reactivity, for example, will often stem from how an individual interprets the event rather than the actual details of the event themselves (Lazarus, 1999).

Regardless of the discipline, there are common factors that all fields can agree upon. Stress is complex. There is no single definition of stress or one correct method of measuring its occurrence or consequences. Stress is universal and enduring. There is no getting away or hiding from stress and, in fact, it would maladaptive to do so. Humans and animals alike must learn to adapt to stressful situations. Research could not and does not strive to eliminate stress. On the contrary, studying the process of stress and its origins will help to uncover solutions for ameliorating or preventing the associated negative health consequences. Examining specific facets within the stress process is important in order to understand the larger stress framework. One of these major facets is the role of perceived control over the stressful event.

Personal Control and Stress Processes

Many studies have documented the role of personal control in the stress process (Grote, et al, 2007; Frazer, Berman, & Steward, 2001). Two traditions have emerged in the literature on perceived control in stress research. The first tradition has relied primarily on self-reports of stressors, distress, and perceived control. Typically, these studies have used checklist inventories of stressful events, such as the Life Event and Difficulties Schedule (LEDS; Brown & Harris, 1978) or The Perceived Stress Scale (Cohen, Kamarck, & Mermelstein, 1983) and self-reports of psychological distress like the PANAS (Watson, Clark, & Tellegen, 1988) or Scale of Life Satisfaction (Diener, Emmons, Larsen, & Griffin, 1985).

The other tradition is steeped in experimental research where stressors, like shock, excessive noise, or extreme temperatures, are controlled and manipulated by researchers. In this setting, stressor reactivity is typically obtained via physiological assessment (i.e., cortisol, galvanic skin response, heart rate, etc.). Both traditions have typically relied on a global or trait conception of perceived control.

Building on these two schools of thought, this dissertation focuses on the role of event-specific perceived control in the stress process and how it is associated with physiological health. The innovation of this dissertation is that it combines self-reports of daily stressors and physiological assessments of distress to evaluate how naturally occurring stressors affect a physiological marker of stress. In addition this research investigates both trait and state components of perceived control as important moderators of the stress process.

There are three papers included in this dissertation. The first paper will identify and investigate the construct of daily control as it relates to the stress process both between and within individuals. The second paper focuses on a key component of the stress process, the hormone cortisol. The goal of this paper is to validate the measurement of diurnal rhythms of cortisol in a non-laboratory setting. The third paper will integrate the concepts of papers one and two to use event-specific control to predict an objective measure of physiological well-being, the hormone cortisol.

Perceived Control: A Theoretical Background

The concept of perceived control has received much attention in psychosocial literature. Among researchers in the field, there is little consensus regarding the exact definition of perceived control. A search for "perceived control" in PsycINFO or Proquest returns a multitude of string of concepts including, but not limited to, self-control, locus of control, emotional control, control attributions, learned helplessness, efficacy, self-determination, theory of planned behavior, sense of control, optimistic bias, and preventability (Klein & Helweg-Larsen, 2002; Jacelon, 2007). Many scholars have attempted to provide parameters for the construct, perhaps none more successfully than Ellen Skinner in her book, *Perceived Control, Motivation, and Coping* (1995). This dissertation uses Skinner's model to organize literature on perceived control into four main domains: locus of control, causal attributions, learned helplessness, and self-efficacy. While these four domains are by no means comprehensive of the vast literature on control, they are the four most widely studied areas of perceived control.

Locus of Control (LOC) refers to an individual's interpretations about how outcomes of an event have been achieved, either due to internal attributes or external forces. The concept was originally coined by Rotter (1966) and later revised by Lefcourt (1976). An individual with an internal LOC attributes consequences of events to their own actions (i.e. "I scored high on that exam because I studied hard and was well prepared"). Alternatively, those with an external LOC view consequences as a result of "luck" or some other outside force (i.e. "I did not receive an A in that class because the professor does not believe in giving out such high grades."). Having an internal locus of control is predictive of a variety of positive outcomes in many different domains (Skinner, 1995). Locus of control is assumed to be a stable characteristic, or trait of an individual, one that does not vary over time.

Causal Attributions (Weiner & Graham, 1985) builds upon the existing Locus of Control literature by including "stability" within the realms of internal and external. When unpredicted events occur, individuals' natural inclination is to try and make meaning of the experience (Skinner, 1995). Accordingly, more than an internal or external attribution, stability or instability of an event has important implications for consequences.

A third component is Learned Helplessness, originally documented by Seligman in 1975 (Miller & Seligman, 1975). People experience negative events on a regular basis. Learned helplessness develops in response to a sustained aversive event that remains, even after attempts to remedy the situation. They perception is that one is in essence, helpless. “As a result, when one is subsequently placed in a situation in which events actually are objectively contingent, these perceptions are generalized, and people behave as if they were still in a noncontingent situation” (Skinner, 1995, p. 22). The phenomenon of learned helplessness has been replicated not only in humans (Miller & Seligman, 1975), but in other species such as dogs, (Maier & Seligman, 1967) cats, (Zielinski & Soltysik, 1964), and fish (Padilla, Padilla, Ketterer, & Giacolone, 1970).

Self-efficacy (Bandura, 1977) is perhaps the most popular construct in literature on perceived control. A PsychINFO search of “self-efficacy” in the title of an article revealed over 4,500 responses. According to Bandura, perceived self-efficacy is defined as individuals’ beliefs about their capabilities to produce designated levels of performance that exercise influence over events that affect their lives, noting, “self-efficacy beliefs determine how people feel, think, motivate themselves and behave” (Bandura, 1993, p. 71). Many of Bandura’s classic experiments examine how differing levels of control result in varied outcomes. In an experiment studying the effects of self-efficacy over cognitive stressors, some participants had the ability to exercise full control over their mathematical tasks, while others were cognitively strained and did not have this luxury. All mathematical tasks were presented on a computer monitor. Control was manipulated by allowing participants in the high control condition to press a button to move on to the next problem, thus controlling the pace. Those in the low control condition “were presented the same problems, but at a pace that exceeded their cognitive capacities” (Bandura, 1988; p. 481). Results showed that participants who were given less control over their cognitive stressors were less likely to bear pain stimulation at a later time (Bandura et al, 1988). Bandura has shown perceived self efficacy has effects on cognition (Bandura, 1996; Bandura, 1993), career aspirations in children (Bandura et al., 2001), depression (Bandura et al., 1999), psychobiologic functioning (Bandura, 1992), anxiety (Bandura, 1991), and coping with cognitive stressors (Bandura et al., 1988).

Differentiating Constructs of Control

There are four distinctions Skinner makes in comparing these four theories of perceived control (Skinner, 1995; Skinner, 1996). The first distinction is whether the construct can be used to *interpret* actions, such as in causal attributions and locus of control theories, versus those that are used to *regulate* behavior, as in self-efficacy and learned helplessness (Skinner, 1995). If the focus of perceived control is on performance of a task, the theory is based on interpreting actions. "I lost the match today because the umpire made bad calls" is an example of an externally focused locus of control that is used to interpret performance. "No matter how hard I study, I just do not understand compound fractions" is a statement high in learned helplessness which would regulate a person's future actions.

Self-efficacy and performance expectations are regulatory beliefs, which in the causal chain of events, are both hypothesized to directly precede behavior (Skinner, 1995). Closely related to this distinction is how perceived control beliefs are related to outcomes. The second distinction for perceived control is *proximal* versus *distal* effects of beliefs on behavior. In other words, control beliefs that are used to interpret performance are more distal than those that are used to regulate actions. By definition, if one is interpreting performance, the action has already taken place, and therefore the proximity is lower than beliefs used to regulate future actions.

Another distinction is based on whether the perception of control is objective versus subjective versus the "experience of control" (Skinner, 1996). Objective control is based on the actual amount of control an individual has over a situation. The basic tenet of learned helplessness research focuses first on objective control in that the subject literally has no control over an aversive stimulus, for example. Even in subsequent trials, when the subject may have control over the stimulus, they perceive they do not. This is now an example of subjective control. Psychosocial research in humans is often much less concerned with objective control. Different than objective or subjective control, the experience of control refers to an individual's "feelings as he or she is interacting with the environment while attempting to produce a desired or prevent an undesired outcome" (Skinner, 1996; p. 551).

The final distinction in perceived control constructs is whether beliefs are *general* versus those that are *specific* to situations. This distinction may seem trivial, but in fact has vast implications for behavior. Locus of control theories are based on general perceptions of how an individual perceives control in his or her environment. A high school senior who states, "I can get into any college for which I apply" has a general control belief about their ability to pursue a college education. Alternatively, the same student reading an application for a financial aid says, "I know I can obtain this scholarship" is an example of a specific control belief. The notion of general versus specific control beliefs is the most central to this dissertation. How control is measured and obtained from an individual is vital if one believes that there is indeed a difference between general perceptions of control and control measured in the context of specific stressful events.

Conceptualizing Control for this Dissertation

Utilizing Skinner's model for control, in this dissertation, perceived control will be conceptualized into two areas, trait perceived control and event-specific perceived control. Trait control is measured with a scale of locus of control (the actual scale is discussed in greater detail in the method section of paper 1), with items such as, "When I really want to do something, I usually find a way to succeed at it" (Personal Mastery) or "There is really no way I can solve all the problems I have" (Perceived Constraints). As previously described, locus of control is thought of as a trait of an individual because it is based on a general set of beliefs of how an individual interacts with their environment to achieve a desired set of outcomes. Even when an event has passed, an individual's locus of control affects the interpretation of the event details.

More essential to this dissertation is event-specific control or perceived control as it relates to a stressful event. In contrast to trait levels, event-specific control pertains to a proximal event and can fluctuate from event to event within an individual. In other words individuals may feel that they have more control over some events (i.e. work deadlines) than other (i.e. being stuck in traffic). Trait levels may influence one's perceptions of control during or after an event, but these two constructs could be essentially independent of one another depending on the context of the stressful event. In addition, due to the proximity to the stressor, event-specific perceptions of control are hypothesized to have a stronger link to outcomes than the more distal trait levels of locus of control.

While there are many potential outcomes one could examine in relation to perceived control, this dissertation will focus on the role of perceived control in the stress process as it relates to physiological health. A brief review of the literature on control as it relates to health outcomes may be helpful.

Perceived Control and Health and Well-Being

There is a well-established relationship between perceptions of control and health and well-being consequences (Rodin & Timko, 1992). However, the vast majority of these studies have focused on control as a stable trait of the individual. For example, one study investigated the relationship between perceived control and sociodemographic and behavioral determinants of health in a sample of over 11,000 individuals ages 20 to 80. SES was operationalized as Work Status, Education, and Income. The authors found global measures of perceived control were related to self-rated general health and health-related behaviors such as frequency of leisure physical activity, smoking, alcohol consumption, and having blood pressure examined by a health professional (Bailis et al., 2001). This article is one example of many studies that do not consider variability in perceived control, across situations, within individuals. Instead, perceived control is assumed to be a stable factor of an individual instead of as a variable that may change across time or context.

Studies that acknowledge there is variability in perceived control often have small samples or very controlled settings. For example, in one such study of older adults aged 72 to 99, variability in perceived control across three health domains was related to self-reported health outcomes (perceived health, chronic health conditions, functional status) and objective measures of physician visits and hospitalizations. Domain-specific variability in control was associated with poorer health, poorer functional status, and more physician visits and hospital admissions (Chipperfield, Campbell, & Perry, 2004). While this study had a small, homogenous sample, one advantage of the research is that it included both psychological and physical health. For the most part, these two facets of health have been treated as separate consequences in perceived control literature.

Perceived Control and Psychological Well-Being

There is a rich history of the effects of perceived control on psychological well-being. Almost uniformly, studies have shown that individuals with higher trait levels of perceived control over their lives have better long-term consequences (Smith et al., 2000). For example, higher trait perceived control has been related to greater life satisfaction (Nunchuck, 1992, Lachman & Weaver, 1998), and lower depressive symptoms (Lachman & Weaver, 1998, Brown 2007.). Other studies focusing on perceived control have found positive associations between subjective well-being (Lang & Heckenhausen, 2001), positive affect (Ruthig, et al., 2007a), and fewer negative emotions (Ruthig, et al., 2007b).

Grob, et. al (1996) measured the effects of perceived control on subjective well-being in a cross-cultural study on European and Western adolescent populations. Results showed trait perceived control was an important factor in the prediction of subjective well-being and that those participants with higher perceptions of control had higher well-being (Grob, 2000). Another interesting finding was that European adolescents had higher reports of control than Western adolescents suggesting that there may be social or system effects of perceptions of control. The author concluded that one limitation of their study was the use of general scales of perceived control rather than domain-specific assessments.

Control and Physiological Health

Physiological measures are often outcomes in experimental settings. In a series of experiments, participants were asked to perform difficult mathematical equations. One study showed participants with lower self-efficacy had higher blood pressure and pulse pressure (Sanz, Villamarin, & Alvarez, 2006). In a similar task, individuals with higher self-efficacy experienced a smaller increase in heart rate and systolic pressure, a greater increase in diastolic pressure, greater reduction in skin temperature, and a reduction in pulse pressure during task performance (Sanz & Villamarin, 2001).

In a study examining the effects of perceived control on biological and subjective stress, there were no effects for trait levels of perceived control on salivary cortisol. However, locus of control moderated the relationship such that "among individuals who perceived they had greater control over a stressful event, those with more internal LOC scores evidenced a smaller cortisol response" (Bollini, et al., 2004 p. 258). In this study, stress was operationalized by using a loud noise, while subjective stress was measured via a subjective stress scale.

Finally, in a longitudinal investigation of 1,210 adults, trait perceived control was shown to be significantly associated with a variety of physical health related behaviors. Participants with a low sense of control had more illnesses, higher rates of bed confinement, and greater feelings of dependence on their doctors. Alternatively, those with a higher sense of control had more instances of self-initiated preventative care and higher self-rated health (Seeman & Seeman, 1983).

Role of Control in the Daily Stress Processes

The majority of research on the role of perceived control and stress processes has either relied on laboratory designs or one-time, self-report studies. The current dissertation uses a daily diary approach to investigating perceived control in the stress process. An advantage of daily diaries is the ability to measure events and experiences in the context and situations in which they normally occur (Bolger, Davis, & Rafaeli, 2003). By allowing measurement of stressors in their original setting, it is also possible for researchers to obtain information not only about the actual event but the behaviors, emotions, and events leading up to the and immediately following the stressor (Bolger & Laurenceau, 2005). In addition, advances in technology have made it easier to communicate with participants, decreasing the necessity for face-to-face interviews. The advancement of sophisticated, multi-level analytic techniques has also provided investigators with new reason to conduct daily diary studies. For example, daily diaries allow researchers to examine event-specific perceptions of control rather than only assessing trait levels of control. In addition, multi-level models allow for the simultaneous estimation of between and within-person variation in perceptions of control.

One study has examined the role of trait perceived control over naturally occurring stressful events. By utilizing participants' responses to a daily questionnaire on stressful events, Neupert and colleagues (2007) examined the role of trait levels of control in stress reactivity. Participants in this study came from a nationally representative sample of adults, aged 25-74. The authors found that responses to stressful events varied by both trait levels of control within the individual as well as by the characteristics of the stressor. For example, on days when no stressors occurred, trait levels of control had less affect on physical and psychological distress. However, on days when a stressor occurred, individuals with high personal constraint and individuals with low levels of mastery had higher distress symptoms (Neupert, Almeida, & Charles, 2007). The current dissertation builds on this research by considering both how trait and event-specific control affect daily stressor reactivity.

Proposed Research

While there is a rich literature on individual perceptions of control, there are also inconsistencies that should be addressed. Researchers often imply control to be a trait or that it may be event-specific, but are not explicit in describing the differences between these two different phenomena. Using self-efficacy as an example, Bandura refers to "people" or "individuals" *who* possess high or low self-efficacy (Bandura, 1977; 1988). This implies self-efficacy is a trait of an individual. Yet, in later articles, Bandura describes "conditions" or "situations" *when* self-efficacy can either be low or high, such as in coping with anxiety (Bandura, 1991) or depression (Bandura, et al., 1999).

The present dissertation hopes to extend this previous literature by investigating perceived control in daily stress processes. The overall goal of this research is to 1) describe the construct of daily event-specific control as it relates to trait levels of control, 2) examine parameters of salivary cortisol in a nationally representative sample, and 3) examine the role of event-specific control in the relationship between daily stress and outcomes of physiological health, salivary cortisol. These goals will be addressed in three papers.

Paper 1: In the Driver's Seat? Event-Specific Perceptions of Control over Daily Stressful Events

The aim of Paper 1 is to address how perceived control over stressful events may vary according to the context in which the event occurs. Control has often been viewed as a stable trait of an individual. While control may be measured on a global scale, contextual factors may play an important role in overall perceptions of control as well as in the variability of control within an individual. Investigating control in a daily approach allows one to examine not only how people differ from each other in their perceptions of control, but also how individuals differ from themselves (within-person variation) depending on daily contexts. One such context that may shed light on trait vs. state control is in response to daily stressful events. There are four research questions associated with this paper. 1) What is the distribution of event–specific perceived control between and within individuals in a nationally representative sample of adults? Is variation in event specific control higher between or within individuals? 2) Does perceived control vary according to context? How might control differ according to stressor-specific experiences? 3) How does event-specific control vary by trait levels of personal mastery and perceived constraint? Does trait level perceptions of control differentially predict event-specific control based on the stressor experienced? 4) How might event-specific control vary by individual characteristics such as age, gender, and education?

Paper 2: The Feasibility of and Considerations for Collecting Salivary Cortisol in a Naturalistic Setting

Cortisol is a hormone regulated by the HPA-axis and is commonly referred to as the "stress hormone" because of heightened secretion in the physiological response to stressful events (Dickerson & Kemeny 2004; Nicolson, Storms, Ponds, & Sulon, 1997). The goal of this paper is to describe the feasibility of collecting diurnal cortisol in a naturalistic setting where researchers relinquish control, allowing participants to experience stressors as they normally occur. In addition this paper also describes considerations for maximizing compliance and increasing the validity of salivary cortisol assessments. In doing so, four issues will be discussed that represent potential problems or "flags" for researchers wishing to study cortisol outside of a laboratory setting (e.g. individuals who sleep for more than 12 hours in a day). There are three research questions for this paper. 1) After examining potential problems, or "flags", related to cortisol collection in a natural setting, how will accounting for these flags affect patterns of the diurnal rhythm of cortisol? 2) Because cortisol is collected at various points in the day, one can test how problem flags affect the parameters of the diurnal rhythm as well as how individual collection points are affected by problem flags. In other words, how are individual occasions of cortisol collection affected by individual problem flags related to cortisol collection? 3) How will results for the present study compare to previously published salivary cortisol data where investigators had more control over their participants and the saliva collection protocol? Will diurnal parameters of cortisol be similar for these two types of studies?

Paper 3: Age Differences in the Predictive Effect of Event-Specific Control on the Diurnal Rhythm of Salivary Cortisol

If perceived control over daily stressful events is related to health, researchers need to explore a better assessment of daily perceptions of control. By examining perceived control in response to specific stressful situations, this paper will test for an association between event-specific perceived control and consequences related to health and well-being. One innovation of this paper, compared to previous research, is stressors will be measured in the context in which these events naturally occur. Using multilevel models, perceived control over daily stress events will be used to predict physiological (diurnal rhythms of salivary cortisol) health. There are four research questions for this paper. 1) Does event-specific control predict parameters of the diurnal rhythm of cortisol for different types of stressful events? 2) After examining different types of stressors, what is the predictive effect of event-specific control over all types of stressors? 3) Does age moderate the effect of control on these parameters? 4) How do trait measures of control moderate the effects of event-specific control on cortisol parameters?

The final chapter will serve as a conclusion and integration of the three papers. Paper 1 describes the construct of event-specific control. Paper 2 describes the diurnal rhythm of salivary cortisol. Using event-specific control and cortisol, the third paper will take findings from papers 1 and 2 to measure the predictive nature of control on a physiological outcome of stress. Finally, all three papers will describe how these phenomena are embedded in the daily stress process and discuss implications for short-term and long-term health.

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CHAPTER II

IN THE DRIVER'S SEAT?

EVENT-SPECIFIC PERCEPTIONS OF CONTROL OVER DAILY STRESSFUL EVENTS

Introduction

"Adversity is a fact of life. It can't be controlled. What we can control is how we react to it."

– anonymous

You miss the bus for work. Upon arriving, your boss tells you she needs those latest figures by noon, but somehow you never received the memo. Just after lunch, your phone rings. The nurse at your child's school calls to inform you that your eight year-old has come down with an ear infection and must be taken home immediately. All of this and you still have to plan tonight's dinner party for your spouse's supervisor. While these events may all be described as "stressful", the consequences may vary greatly depending on how much control the individual perceives to have over each of the events.

The extent to which an individual feels he or she can dictate the outcome of a potentially stressful event has a great effect on the event's outcome and potential consequences. *Perceived control* refers to "expectations of being able to participate in making decisions and engaging in actions in order to obtain desirable consequences and avoid unfavorable ones" (Rodin, 1986; p. 6). The amount of control one feels over an event is closely tied to how predictable the event may be and thus the effect of the event on well being (Pearlin, 1999). For example, events representing a disruption in one's daily routine, such as meeting an important deadline for work, will have a greater negative impact if the event is unplanned. It is therefore expected that meeting important deadlines will be stressful; however consequences of the event will vary greatly should one have months to prepare for it versus a supervisor informing you the morning of that they need a report in a few hours.

Although the role of perceived control has been widely documented in the stress process (Grote et al, 2007; Bollini et al., 2004, Shirom, Melamed, & Nir-Dotan, 2000; Bowman & Stern, 1995), little is known about the temporal structure of control. Is control a stable trait of the individual or a characteristic susceptible to fluctuation based on the situation or context? The overarching goal of the paper is to address how perceived control over stressful events may vary according to the context in which the event occurs. We define situation-dependent control as event specific control (ESC), or the amount of control one perceives to have over a particular event. The aims of the present study are to a) assess the amount of between- and within-person variation in ESC, b) examine how the level of ESC differs by the type of stressor experienced by the individual, c) examine the association of trait measures of perceptions of control (TPC) with ESC and then d) to explore how age, gender, and socioeconomic status moderate the associations between TPC and ESC.

Perceived Control: Trait versus State

Control has often been viewed as a stable trait of an individual. While control may be measured on a global scale, contextual factors may play an important role in overall perceptions of control as well as in the variability of control within an individual. In order to assess contextual features we examine control in a daily approach, which allows us to examine not only how people differ from each other (between-person variation) in their perceptions of control, but also how individuals differ from themselves (within-person variation) depending on the context. One such context that may shed light on trait vs. state control is in response to daily stressful events.

<u>Control as Trait.</u> Traditionally, control has been measured as a stable characteristic, or trait, within an individual. According to Bandura, perceived self-efficacy is defined as people's beliefs about their capabilities to produce designated levels of performance that exercise influence over events that affect their lives, noting, “self-efficacy beliefs determine how people

feel, think, motivate themselves and behave" (Bandura, 1994, p. 71). Many of Bandura's classic experiments examine how differing levels of control between individuals result in varied outcomes. In an experiment studying the effects of self-efficacy over cognitive stressors, some participants had the ability to exercise full control over their mathematical tasks, while others were cognitively strained and did not have this luxury. Results showed that participants who were given less control over their cognitive stressors were less likely to bear pain stimulation at a later time (Bandura et al, 1988). Bandura has shown perceived self efficacy has effects on cognition (Bandura, 1996; Bandura, 1993), career aspirations in children (Bandura et al., 2001), depression (Bandura et al., 1999), psychobiologic functioning (Bandura, 1992), anxiety (Bandura, 1991), and coping with cognitive stressors (Bandura et al., 1988). In all of these experiments, self-efficacy was measured as a stable trait of the individual.

Control over stressful situations has also been studied with animals. Seligman and Maier's concept of learned helplessness refers a phenomenon that when "events are uncontrollable the organism learns that its behaviors and outcomes are independent, and that this learning produces the motivational, cognitive, and emotional effects of uncontrollability" (Maier & Seligman, 1976; p. 1). Learned helplessness research focuses on an animal's reaction to a stressful event in which their actions cannot determine escape from the stressor. For example, one such experiment, Seligman and Visintainer (1985) studied control by injecting rats with live tumor cells and subjecting them to stressful stimuli. They found that rats that were placed in a situation in which shock was unavoidable were more likely to develop tumors and die compared to rats in similar conditions, but who could escape the shock. These findings have been extended to include dogs, (Maier & Seligman, 1967) cats, (Zielinski & Soltysik, 1964), fish, (Padilla, Padilla, Ketterer, & Giacolone, 1970), and humans (Miller & Seligman, 1975).

For the most part, such as in the case of self efficacy and learned helplessness research, perceived control has been measured as a stable trait. An individual is likely to have global perceptions about their ability to control outcomes in their life. Lachman & Weaver (1998) utilized two measures of trait control, personal mastery and perceived constraints. "*Personal mastery* refers to one's sense of efficacy or effectiveness in carrying out goals while perceived constraints indicate to what extent one believes there are obstacles or factors beyond one's control that interfere with reaching goals" (Lachman & Weaver, 1998; p. 554). The authors found there were only moderate correlations among each of the domains. In addition, results showed that trait measures of personal mastery and perceived constraint were significantly correlated with 7 control domains. These results suggest that perceived control is a multidimensional construct with both domain-specific and global perceptions of control. Both types of control may play important roles in daily stress processes.

For example, one study examined the association of trait levels of perceived control on reactivity to daily stressful events (Neupert, Almeida, & Charles, 2007). Results showed individuals with higher perceived control showed lower emotional and physical response to daily stressful events. However, these effects were moderated by the age of the individual, as well as the type of stressor they experienced. The finding of variation in stressor reactivity suggests evidence that perceptions of control vary in different contexts and therefore must be examined as a state-like process within an individual.

<u>Control as a State.</u> While trait levels of control have been studied in both experimental and naturalistic settings, researchers have recently begun investigating the possibility that control could vary depending on the context of the individual. One way to address these two types of control would be to examine perceptions of control on a daily basis. Daily measurements of

control allow researchers to examine the amount of variation that exists between individuals (trait-level) versus the amount of variation that exists within individuals across occasions of measurements and situations (state-level). In other words, is an individual more likely to differ from another person or more likely to differ from themselves from day-to-day? This is the basis for the first research question addressed in this paper.

Ong and colleagues (2005) examined the effects of daily perceived control and stressors on anxiety in a sample of recently widowed women. Results revealed an interaction between control and stressful events on daily anxiety. On days when widows reported feeling more in control, there were weaker associations between stress and anxiety. Additionally, widows who experienced more stress, or who reported lower feelings of daily control displayed heightened response to daily stressful events.

Accordingly, it may be the case that individuals possess a global amount of personal control and still show variations across situations, contexts, or events (Eizenman, Nesselroade, Featherman, & Rowe, 1997). This is important because it suggests that in order to obtain an accurate depiction of perceived control's role in the stress process, one examine both trait levels of control and context-specific perceptions of control. To date, very few studies have examined longitudinal stability/variability in perceived control. Eizenman and colleagues (1997) measured locus of control and perceived competence on a weekly basis for 7 months in a sample of older adults. Their findings suggest there is evidence for intraindividual variability in control beliefs such that it is normative for adults to show variation in the daily scores of personal control. However, intraindividual variability in perceived control was greater in older individuals compared to their younger counterparts (Eizenman, et. al, 1997), suggesting there are interindividual differences in intraindividual variability of perceived control. In the words of the authors, the finding that there is intraindividual variability in perceived control, "argues for broadening the conception of perceived control beyond being a stable, trait-like attribute to include recognition of a dynamic process as well. This is not to downgrade the role of consistent differences in level of perceived control. Rather it is an argument favoring the inclusion of lability in the modeling of apparently key personality processes." (p. 499). Accordingly, in a sample of elderly adults, Chipperfield and colleagues found that variability in perceived control was associated with poorer health outcomes (Chipperfield, Campbell, & Perry, 2004). This supports findings from Eizenman et al. (1997) that variability in perceived control predicted mortality.

Instead of treating within- person variability in control as a potential source of error, one could examine control over stressful events by incorporating this variability into the study design. As previously discussed, one study has examined the role of control over naturally occurring stressful events. By utilizing participants' responses to a daily questionnaire on stressful events, Neupert and colleagues (2007) examined the role of trait levels of control in stress reactivity. The authors found that responses to stressful events varied by both trait levels of control within the individual as well as by the characteristics of the stressor.

Contexts of Stressors

There is a growing body of literature which recognizes that control may vary in different contexts. Lachman and Weaver (1998) have shown that adults have differentiated perceptions of control depending on different domains of life. This paper documented seven domains of control: finances, sex, contributions, work, child, health, and marriage. On average, adults reported feeling least in control over their finances and sex lives, and most in control over their marriages and their overall life. However, depending on the age of the respondent, perceived levels of control varied in different domains. For example, older adults reported feeling in greater control of their overall life compared to younger or midlife adults. In contrast, middle aged individuals showed highest perceived control in the domain of finances, higher than both younger and older adults. In light of these results, one of the aims of the current study is to explore how individual characteristics, such as age, relate variation in perceptions of control.

Krause (2007) examined role-specific control in the most highly valued roles as defined by the participants in the study. Krause provided the participants with 8 different potential roles (e.g. spouse, parent, grandparent, etc.), allowed the participant to choose which was most important, and then measured control based on the specific roles and found that control differed based on roles that were more salient to individuals. Rees & Cooper (1992) measured locus of control over occupational stress and found that there were differences in control based on specific job-related tasks within an occupation. The authors note, "These findings are theoretically consistent with the argument that [locus of control] is a subjective measure rather than a trait construct" (p. 45).

The authors in this study investigated the role of trait levels of control on various stressful events. Given their results, one way to expand on this research would be to question whether perceptions of control vary based on stressor-specific experiences. This is the basis for the second research question addressed in the present study, which will examine perceptions of control on three types of stressors, interpersonal stressors, overload stressors, and network stressors. A description of each type of stressor will follow in the methods section.

It is with these studies in mind that the present study examines daily perceived control along with trait control. Instead of treating these as two separate or competing processes, it may be the case that these constructs are both present within an individual at different levels. An individual may have global or trait levels of control that may act upon their perceptions of control in specific situations or domains. The present study will examine how trait control and daily perceived control are related to one another in the course of the stress process.

Moderators of Control

Regardless of whether control is measured as a trait of the individual or as a context-specific characteristic, many global factors are associated with control. The following section explores some of these factors.

Age. Age differences in levels of control are well documented in research literature. There is strong evidence that there is a negative relationship between age and control and that control in the elderly tended to be more externally rather than internally focused (Lachman, 1986; Skinner, 1990; Aldwin, 1991; Lachman, 2006). Many studies have focused on control beliefs over health-related domains, suggesting there may be differences in control according to specific contexts. In the study over “role-specific” control, mentioned previously, results showed control declined across later life (Krause, 2007).

Gender. Compared to age differences, gender differences in perceived control have been less widely explored. One study examined gender difference in perceived control among college students in emotionally abusive relationships (Clements, Ogle, & Sabourin, 2005). Results showed women reported lower control over relationship conflicts than men and that even men who were experiencing high levels of emotional abuse had higher perceived control than women experiencing low levels of abuse. Another study, however, found females reported higher perceptions of control over planned behavior to prevent sexually transmitted diseases (Munoz-Silva, Sanchez-Garcia, Nunes, & Martins, 2007). In addition, females with higher perceived control were more likely to use condoms. In a literature review of gender differences in perceptions of control, Sherman, Higgs, & Williams (1997) note that females tended to have higher perceived control over interpersonal relationships, while males have higher perceived control over "uncontrollable" life events, such as international affairs and regional conditions.

Socioeconomic Status. Even fewer studies have examined the role of socioeconomic status (SES) and perceptions of control but the few that have show consistent findings. In addition, these studies have focused exclusively on trait constructs of control. For example, one study on teenagers in South Africa found SES was positively related to locus of control (Maqsud & Rouhani, 1991). In a study of British adults, SES was also positively related to perceptions and behaviors related to weight control (Wardle & Griffith, 2001). One last example focused on perceptions of control in financial coping strategies (Caplan & Schooler, 2007). Results showed that SES was positively related to perceptions of control. The authors noted, these results suggest that low SES may decrease one's control beliefs, which in turn decrease the likelihood of choosing effective financial coping processes, resulting in double disadvantage" (p. 43).

The Present Study

The present study examines how perceived control may vary by different stressful experiences. As previously mentioned, global measures of personal control have been valuable to stress research (Thoits, 1983; Reich & Zautra, 1984, Ong, et al., 2005). However, it may be the case that research can be better informed by measuring control in specific context concurrently with global measures. Accordingly, in addition to measuring trait levels of control, the present study also incorporates event-specific perceptions of control (ESC). Utilizing a national sample, this study will address the following research questions.

Research Questions

1. What is the distribution of ESC in a national sample of older adults? Is variation in ESC higher between or within individuals?
2. Does ESC control vary according to context? How might ESC differ according to stressor-specific experiences?
3. How does perceived control vary by trait levels of personal mastery and perceived constraint? Does trait level control differentially predict daily perceived control based on the stressor experienced?
4. How might perceived control vary by individual characteristics such as age, gender, and socioeconomic status (using education as a proxy)?

Method

Participants

Participants for the present study come from the initial set of respondents participating in the second wave of the National Study of Daily Experiences (NSDE, N = 1,265). Participants for the NSDE come from a subsample of the National Survey of Midlife in the United States (MIDUS II), a nationally representative telephone-mail survey of 4,963 people aged 35-84, carried out in 2003-2004 (For a review of the MIDUS II sample, as well as comparisons between samples in MIDUS I and II, see Costanzo, Ryff, & Singer, 2009). Participants in the NSDE completed short telephone interviews across eight consecutive evenings about their daily experiences. The current response rate for the study is 76% with a retention rate of 96%. On average participants provided a mean of 7.5 interviews per 8 days (summing to a total of 10,120 interview days). Table 1 shows demographic characteristics of both the MIDUS II and NSDE II samples.

Insert Table 1 about here

Recruitment and Interview Procedure

Approximately 9 years after completing the first wave of data, participants were recruited by MIDUS II (phase 1) to complete a baseline interview, a 45 minute telephone interview covering a host of psychosocial and demographic variables, as well as a 100 page, self-administered questionnaire. For an in depth review of all of the scales completed in MIDUS, see Brim, Ryff, & Kessler, 2004; Lachman & Weaver, 1998; and Keyes & Ryff, 1998. Three months after completion of phase 1, participants were then contacted by the NSDE. Approximately one week before telephone contact, NSDE participants received a package containing a recruitment letter and a summary of previous findings and a check for $25. Approximately one week after recruitment mailing, an initial call was made to participants requesting their participation in the study. The daily telephone interview consisted of time use (including social support), physical symptoms, alcohol and tobacco use, negative and positive affect, productivity, in-depth assessment of stressors, positive events, medications, and a weekly review (on day 8 only).

Measures

Personal Mastery and Perceived Constraint

Control belief variables were assessed in the MIDUS survey. These measures were developed from Pearlin and Schooler's (1978) mastery scale with five additional items specifically designed for the MIDUS (Lachman & Weaver, 1998). Respondents rated on a 7-point Likert scale (1 = strongly agree, 7 = strongly disagree) how strongly they agreed with each statement. For the mastery scale, participants responded to the following statements: a) I can do just about anything I really set my mind to; b) When I really want to do something, I usually find a way to succeed at it; c) Whether or not I am able to get what I want is in my own hands; and d) What happens to me in the future depends mostly on me. Responses were coded so higher scores indicated greater personal mastery for each person (Chronbach's $\alpha = .70$). For the constraints scale, participants responded to the following questions: a) There is really no way I can solve all the problems I have; b) There is little I can to do change the important things in my life; c) I often feel helpless in dealing with the problems in life; d) Other people determine most of what I can and cannot do; e) What happens in my life is often beyond my control; f) There are many things that interfere with what I want to do; g) I have little control over the things that happen to me; and h) I sometimes feel I am being pushed around in my life. Responses were coded so higher scores indicated greater perceived constraints for each person (Chronbach's $\alpha = .86$). These measures have been used successfully as valid indicators of personal mastery and perceived constraints in several studies (e.g., Lachman & Firth, 2004; Lachman & Weaver, 1998).

Daily Stressful Events

Daily stressors were assessed through the semi-structured Daily Inventory of Stressful Events (DISE, Almeida et al., 2005). The inventory consisted of a series of seven stem questions asking whether different types of daily stressors (i.e., arguments, potential arguments, work stressors, home stressors, network stressors, discrimination stressors, and other stressors) had occurred in the past 24 hours. For example, participants were asked, "In the past 24 hours, have you experienced anything at work that most people would consider stressful". Individuals who responded "yes" to a stem question received a value of one for that stressor. The present study utilized three stressor domain variables: interpersonal stressors (arguments, tensions, or stressors involving other people; 50% of all stressors reported), overloads (demands that tax the individual or stressors not involving other people; 38% of all stressors reported), and network stressors (whether anything happened to a close friend or family member that turned out to be stressful for the respondent; 12% of all stressors reported). Interpersonal, work, home, and network stressors represent 87% of all stressors reported. The remaining 13% of stressors included experiences of discrimination (1.2%) and those not falling under any specific category (11.8%). In terms of the overall daily diaries, interpersonal stressors occurred on 21% of days, overload stressors occurred on 16% of days, and network stressors occurred on 5% of days.

Event Specific Perceived Control (ESC)

Perceived control was measured in the context of a daily stressful event. An affirmative response to a stressor stem question resulted in obtaining detailed information about the event. Control was measured using the question, "During this situation, how much control were you feeling?" Responses to this question were measured by a 4 point Likert scale including, "none at all", "a little", "some", or "a lot" where 1 = "not at all" and 4 = "a lot".

Education

The highest level of education reported by the participant was used as a proxy for socioeconomic status. The average participant for the current study reported having at least some college education (13.1 years of education). 30% reported having a high school diploma or less, 49% reported having attending some college but no college degree, and 21% reported having a college degree or higher.

Plan of Analyses

In order to analyze data for the present study, a "person by event" dataset will be utilized. Because of the nature of the data, a common method for data management in daily diary research is to use a "person by day" dataset where an Individual's day 1 data is on the first row of a dataset, day 2 data on the second row, and so forth until the final day of the study (day 8 in the NSDE). Because an individual can have more than one event on any given day, we transform the data such that the each row represents a separate event for an individual. Whereas in the "person by day" NSDE dataset an individual will have a maximum of 8 rows (for the 8 days in the study), in a "person by event" dataset, individuals may have up to 7 rows per day, depending on how many stressful events they experienced on that day. Refer to Table 2 for an example of a person-event data set. Notice each row represents a different stressful event and for each event (the variable "Event" signifies the type of event), the participant has rated their level of perceived control. For each row, Personal Mastery and Perceived Constraint are the same within a participant. Because these are assumed to be trait variables, they were only measured at one time point. Therefore they are the same on every row in the data for a given individual.

Insert Table 2 about here

The main data analysis method will be Multilevel Modeling (MLM; Raudenbush & Bryk, 2002; Snijders & Bosker, 1999), a method that has become increasingly popular among diary researchers to examine both inter-individual and intraindividual variation (Almeida, 2005; Bolger, Davis, & Rafaeli, 2003; Nezleck, 2001; Tennen, et. al, 2000). An important feature of multilevel models is that they can be estimated via full information maximum likelihood, making use of all available data while taking into consideration the amount of data available from each person by giving more weight to persons with complete data than those with some missing data (Little & Rubin, 2002). Thus, instead of deleting all of the respondent's data due to a missed interview, this approach has the advantage of using all available data from a given respondent, and offers unbiased and efficient parameter estimates under the assumption of missing at random (Little & Rubin, 2002).

For illustrative purposes, the simplest form of a multi-level model is one in which an outcome is estimated with no predictors, called an empty or null model as shown in equation 1.

$$\text{Level 1: } \text{Control}_{ei} = \beta_{0i} + r_{ei} \quad (1)$$

$$\text{Level 2: } \beta_{0i} = \delta_{00i} + U_{0i}$$

At level 1, the perceived control for a specific event is a function of an intercept (β_{0i}), reflecting a person's perceived control across all events and a residual error term (r_{ei}), At level 2, the level 1 intercept becomes the outcome and is given as a function of an intercept (δ_{00i}) reflecting a person's event-specific perceived control across the 8 days, and a variance component (U_{0i}) reflecting variability in the average level of perceived control reported across the 8 days.

We can then add a predictor at level 1 as seen in equation (2). Now Event-Specific Control_{ei} is the reported perceived control for Event_e of Person_i, β_{0i} is the intercept indicating Person_i's level of average control on all stressor days , β_{1i} is the effect of stressor type (e.g., tensions, overload) on perceived control and e_{di} is the residual variance or error associated with the event-specific control of Person_i.

$$\text{Level 1: } \text{Event-Specific Control}_{ei} = \beta_{0i} + \beta_{1i}(\text{Stressor Type}) + e_{di} \quad (2)$$

In order to estimate average effects for the entire sample, the intercepts and slopes of the Level 1 within-person model become the outcomes for the Level 2 between-person equations. In equation 3, we have also added the slope for an person i's trait control as follows:

$$\text{Level 2:} \quad \beta_{0i} = \delta_{00} + B_{2i}\,(\text{Trait Control}) + U_{0i} \qquad (3)$$

$$\beta_{1i} = \delta_{10} + B_{2i}\,(\text{Trait Control}) + U_{1i}$$

All multilevel models were conducted using the PROC MIXED command in SAS (v. 9.0). Intraclass correlations (ICC) were calculated by running a model with perceived control as the dependent variable and no predictors (empty model).

Results

Descriptive statistics are presented in Table 3. In order to address the first research question, frequency analyses were performed to assess the amount of perceived control respondents had over stressful situations. On average, participants reported having between “some” and “a lot” of Personal Mastery (M = 5.71) and between “a little” and “some” Perceived Constraint (M = 2.56). In terms of event-specific control, individuals perceived having “no control” for 36% of daily stressors, “a little” control for 15% of stressors, “some” control for 23% of stressors and “a lot” of control for 27% of stressors. Results showed the ICC for event specific perceived control was .31. This indicates that 31% of the variance in event specific perceived control was between individuals. The remaining 69% of the variance was within individuals. For all three stressor types, within-person variance was almost two times higher than between-person variance.

Recall the second research question addresses whether daily perceived control varies according to specific-contexts, for the present study, the different types of stressors experiences. Descriptive statistics for trait control and control for each type of stressor are shown in Table 3.

Insert Table 3 about here

As reported earlier, stressors were aggregated into three categories: interpersonal tensions, overload stressors, and network stressors. Referring again to Table 3, on average, individuals reported having the most control over interpersonal tensions (M = 1.78; between “a little” and “some” control) and the least control over network stressors (M = 0.47; between “no control” and “a little control”) with overload stressors in the middle (M = 1.33). In a similar manner as in the first research question, variance was decomposed for each stressor type. A Tukey post-hoc test was performed to test for significant differences in perceived control for each stressor type. Results showed perceived control for each stressor type was significantly different from the other two stressor type.

Trait Control Prediction of Mean Level Daily Perceived Control

The third research question was to determine if event specific control varied as a function of trait levels of personal mastery and perceived constraint. Personal Mastery (PM) was significantly correlated with perceived constraint (PC; $r = -.54$, $p < .001$). Both PM and PC were significantly correlated with event specific perceived control, $r = .11$, $p < .001$; $r = -.14$, $p < .001$, respectively. Table 4 shows mean differences for trait control predicting daily perceived control across all stressors. Individuals with low PM were more likely to report having “no control” and less likely to report having “a lot” of control over daily stressful events. The pseudo R^2 for the model was .12, meaning that 12% of the variance in daily perceived control is explained by trait levels of control.

Insert Table 4 about here

A multivariate analysis was conducted to test the differences in the effects of measures of trait control on each type of stressful event. Results are shown in Table 5. Both PM (B = .144, SE = .03, p < .001) and PC (B = -.18, SE = .03, p < .001) were significant predictors of daily perceived control interpersonal tensions (n = 1,788 events). Furthermore, both PM (B = .15, SE = .04, p<.001) and PC (B = -.15, SE = .03, p < .001) were significant predictors of perceived control regarding overload stressors (n = 1,396). Neither PM (B = .02, SE = .04, p = n.s.) nor PC (B = -.02, SE = .04, p = n.s.) were significant predictors of control over network stressors (n = 460).

Insert Table 5 about here

Moderators

The fourth and final research question tested the moderating effect of demographic characteristics on the association between trait control and daily perceived control. To test for moderation effects, interaction terms were entered into the multilevel models for age, gender, and education and run separately for both Personal Mastery and Perceived Constraints. For a summary of the moderating effects, see Table 6.

Insert Table 6 about here

Age

Results revealed no significant main effects of age on either control over interpersonal tensions or control regarding overload stressors. There was a significant main effect of age for control over network events and measures of trait control. Older individuals perceived higher levels of mastery and higher levels of constraints and more control over network events. There was a significant interaction of age in the relationship between overload stressors and PC (B = .006, SE = .003, $p < .05$; See Figure 1). Younger individuals with lower trait perceived constraints had higher perceptions of control over overload stressors. Older individuals, regardless of trait levels of constraints, perceived lower levels of control over overloads.

Insert Figure 1 about here

Gender

Gender was coded as "0" for males and "1" for females. Results revealed a main effect of gender in the relationship between both PM (B = -.17, SE = .07, $p < .001$) and PC (B = -.14, SE = .07, $p < .05$) on interpersonal tensions. There was also a main effect for gender on overload stressors (PM, B = -.23, SE = .08, $p < .001$) and PC (B = -.22, SE = .08, $p < .001$). The negative coefficients for these models indicate that females reported lower perceived control on interpersonal tensions and overload stressors compared to males. There were no main effects of gender on network events. There were also no significant interactions of gender between trait control and network events.

Education

No significant main effects or moderating effects were found for education for any of the different stressor types.

Discussion

The goal of this paper was to address how perceived control over stressful events may vary according to the context in which the event occurs. Previous literature has documented the role of perceived control in the stress process. This paper extends this line of research by examining event-specific perceptions of control and the moderating effects of trait levels of control.

Multilevel models revealed that within-person variation in event-specific control was almost two times higher than between-person variation. This shows that people are more likely to differ from themselves, based on an event, than they are to differ from other people. Part of this variation was tied to the types of stressor individuals experienced.

Within-person variation is particularly interesting to the current study. The finding that there is more within-person variation than between-person variation in ESC is important because it shows that researchers cannot continue to rely on trait-measurements of control. One of the unique contributions of the current study is the event-specific measurement of control. The fact that there is a significant amount of between-person variation shows that trait measures are not obsolete and are still informative. But, as previously noted (Eizenman et al., 1997) and possibly more importantly, researchers must also include event-specific perceptions of control in order to accurately depict the role of control in the stress process.

Previous studies may have criticized within-person variation as “measurement error”, if it was measured at all. This critique is not valid in the current study for two reasons. First, measurement error is, by definition, not predictable. Although the current study did not attempt to predict within-person variability, future studies could do so with the current sample. Additionally, large standard errors of within a repeated measure are typically a red-flag for higher measurement error (Rosner & Willett, 2008). As shown in Table 4, this is not the case for the current study and we can be confident that, while some of the within-person variation may be due to measurement error, this is in fact due to true variation within individuals across measurement occasions.

Results also showed that on average, individuals perceived the highest level of ESC over interpersonal stressors, or stressors involving other people such as arguments or disagreements. Participants reported having the least amount of control over network stressors, events that were experienced by a person in the participant's life but turned out to be stressful for the participant.

These results should not be surprising for a number of reasons. Network stressors, by definition, were events not directly experienced by the individual, but occurred to someone else, yet were still stressful to the participant. It makes sense that individuals would perceive the least amount of control over these events. Interestingly, individuals perceived significantly higher levels of ESC over interpersonal stressors compared to overloads. One potential explanation for this finding is that individuals have the ability to take more time to deal with interpersonal stressors than overloads. For example, when arguing with a spouse, individuals may choose whether or not to try and resolve it right away or take a step back to collect their thoughts before responding to the event. On the other hand, a deadline at work might need to be responded to immediately. The consequences of inaction or indecision may have higher implications at your job or school. In turn, individuals may feel less control over these events. Furthermore, the amount of control one perceives over an event may have little to do with the problem solving needed to resolve the event. Deciding whether or not to get a divorce would be an extreme example of an interpersonal stressor, whereas day-to-day interpersonal stressors may represent events that can be resolved more easily and thus perceptions of control may be higher in these situations.

Results from the current study also revealed that trait levels of control were significant predictors of event-specific perceptions of control. Individuals with higher personal mastery or lower perceived constraints reported higher overall control over stressful events. These findings are consistent with previous research by Neupert and colleagues (Neupert, et al., 2007). Personal mastery was positively associated and perceived constraints were negatively associated with both interpersonal tensions and overloads. However, neither trait measures of control were significantly associated with network stressors.

Moderating influences of age, and gender, and education were also tested in the relationship between trait control and event-specific perceptions of control. While gender was associated with both interpersonal tensions and overload stressors and age was associated with network stressors, only one moderator was found. Age moderated the effect of perceived constraints on overload stressors such that younger individuals with lower perceived constraints reported higher control over overloads, whereas in older adults, perceived constraints did not have an effect on control over overload stressors. This result is in line with Carstensen's (1991, 1999) socioemotional selectivity theory, which states that as people age, they are more aware of their limited time and consequently seek out interactions, contexts, experiences, and relationships that are more enjoyable and less adversarial. Recall, overload stressors represent events that tax the individual or events not involving other people. Typically, these events occur in the workplace, which makes sense given that younger adults reported more than twice the amount of overload stressors compared to older individuals (2,007 vs. 846). In addition, younger adults also report these events as more stressful (Almeida, 2005) than their older counterparts, which may also help explain the interaction effect. SST may also explain the result that older adults perceived higher amounts of control over network stressors than younger individuals. This may be due to the fact that older adults have had more experiences with these events and therefore perceive them as less stressful.

As previously reported, no main effects or interactions were found for education. Although education has consistently been found to be positively associated with perceived control at the trait level (Caplan & Schooler, 2007; Dohrenwend, et al.,1998; Keenan, Gunthrope, & Grace, 2007), few studies have examined education and event-specific perceptions of control. One reason for the lack of significant results of education in the current study could be because the current sample is highly educated (at least some college). Instead of measuring education as a continuous variable, future analyses could investigate event-specific perceptions of control at the extreme ends of the education spectrum by examining high vs. low income or highly educated vs. less educated individuals. In addition, future studies would benefit from examining other measures of socioeconomic status, such as income or occupational status, in association with perceptions of control.

One of the strengths of this paper is that it incorporates trait levels of control with event-specific perceptions of control. In accordance with Eizenman and colleagues (1997) variation in perceptions of control should be investigated from both the trait and context level. This is the first known study that combines these measures of control to examine the stress process. While trait control is correlated with event-specific perceptions of control, this paper provides evidence that the two measures need to be viewed as distinct and consequentially future studies on perceived control need to be conscious of which phenomenon they intend to measure.

Another strength of the study is the incorporation of different types of stressful events. Perceptions of control have been shown to vary across contexts (Lachman & Weaver, 1998; Ong et al., 2005). The study could have aggregated the experiences and essentially examined the effects of event-specific control on stressful experiences. However, by parsing perceptions of control across different stressful experiences one is able to see that even in a specific domain (i.e. responses to stressful situations) there is variation in how much control is perceived by an individual.

A final strength of the study is the daily diary approach, measuring stressful experiences of individuals across 8 days. An advantage of daily diaries is the ability to measure examination of events and experiences in the context and situations in which they normally occur (Bolger, Davis, & Rafaeli, 2003). While this represents a loss of control (no pun intended) for the researcher, measuring events as they happen to the participant provides greater external validity than inducing stressful situations in a lab and measuring the effects. Perhaps the largest advantage of daily diaries is the ability to test the effects of intraindividual change, interindividual differences in intraindividual change, and the covariation of interindividual differences in intraindividual change. The present study utilized this approach to examine variation in event-specific perceptions of control within an individual, as well as across individuals.

The biggest limitation of the study is the single-item question on event-specific perceptions of control. Ideally, as Skinner (1998) noted, control should be measured as a multi-dimensional process. Given the original study was designed to measure the daily stress process and not perceptions of control in the stress process, we need to view this as simply the first step in investigating event-specific perceptions of control. The fact that there were significant results even in light of this single-item question should be viewed as promising.

While a strength of the study was the daily diary approach, a second limitation is that interviews were conducted only once a day. Reports on the amount of control one perceived was limited to retrospective recall. In some cases the stressor may have occurred just minutes before the phone call yet in other instances the stressor may have taken place up to 24 hours prior to the daily interview. In these latter cases subjective responses in the amount of control perceived by the individual may be confounded with many other factors related to the stressor, rather than simply how much control they had over the event.

To address these limitations, future studies would benefit from more elaborate event-specific control measures. Many studies have adapted general control scales to measure perceived control over specific domains (Rees & Cooper, 1992; Lachman & Weaver, 1998; Krauss, 2007). Ong, Bergeman, & Bisconti (2005) used an adapted version of the Mental Health Inventory (MHI; Veit & Ware, 1983), a nine-item scale measuring behavioral/emotional control. However, this measure was not used to examine perceived control in the stress process. Since perceived control has been well-documented to affect stressor reactivity stress researchers would benefit from developing a structured scale on stressor-specific perceived control.

Another future direction to further perceived control in the stress process could make use of sophisticated technological advances in survey collection, such as personal digital assistants (PDAs), laptop computers, and internet capable cellular phones (Stone, Shiffman, & DeVries, 1999). One of the chief advantages to these types of measurement, broadly referred to as ecological momentary assessments (EMAs) is the wide array of content that can be collected. Respondents can easily report about occurrence of stressful events, physical symptoms, and affective states. Situational characteristics can also be obtained such that individuals can report exactly where they are, who they are with, and what they are doing at the time of measurement, and most importantly for the current paper, the amount of control they perceive over the event.

The current study provides evidence for variation in perceived control based on event-specific stressors. Both trait levels of control within an individual, as well as event-specific perceptions of control are important factors that may have implications on stressor reactivity. In response to a stressor, the amount of control perceived by the individual may affect behavioral, psychological, and even physiological responses. A natural next step from the current study would be to investigate the predictive effects of event-specific control on stressor reactivity outcomes such as physical symptoms, negative affect, or cortisol responses.

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Table 1. Demographic Comparison of the MIDUS Sample and NSDE Sample

Demographic Variable	Breakdown	Wave 1		Wave2	
		MIDUS%	NSDE%	MIDUS%	NSDE%
Age	Young Adults, 25-39	33.2	33.5	9.6	8.3
	Midlife Adults, 40-59	46.0	45.0	43.0	41.9
	Older Adults, 60+	20.8	21.5	47.4	49.8
Gender	Males	48.5	45.5	46.7	42.9
	Females	51.5	54.5	53.3	57.1
Education	12 Years of Less	39.2	37.7	33.4	32.4
	13 Years or More	60.8	62.3	66.6	67.6
Marital Status	Married	64.1	65.4	70.6	72.6
	All Others	35.9	34.6	29.4	27.4
Children in Household	Yes	39.0	37.8	30.6	28.1
	No	61.0	62.2	69.4	71.9
Race	Caucasian	84.1	86.3	85.9	88.3
	African American	10.8	9.7	9.1	8.2
	All other Races	5.1	4.0	5.0	3.5

Table 2. Example of a Person-Event Data Set.

ID	IDDay	Day	Event	GENDER	AnyStress	Control	Mastery	Constraint
100	1001	1	1	1	1	0	6.26	1.08
100	1002	2	2	1	1	2	6.26	1.08
100	1002	2	6	1	1	0	6.26	1.08
100	1003	2	0	1	0	.	6.26	1.08
100	1004	4	1	1	1	1	6.26	1.08
100	1005	5	0	1	0	.	6.26	1.08
100	1006	6	3	1	1	0	6.26	1.08
100	1007	7	3	1	1	2	6.26	1.08
100	1008	8	1	1	1	2	6.26	1.08
302	3021	1	1	0	1	1	4.51	3.78
302	3022	2	1	0	1	3	4.51	3.78
302	3023	3	1	0	1	3	4.51	3.78
302	3023	3	2	0	1	1	4.51	3.78
302	3024	4	1	0	1	0	4.51	3.78
302	3024	4	2	0	1	3	4.51	3.78
302	3025	5	0	0	0	.	4.51	3.78
302	3026	6	1	0	1	1	4.51	3.78
302	3027	7	0	0	0	.	4.51	3.78
302	3028	8	0	0	0	.	4.51	3.78

Table 3. Descriptive Statistics of Control.

	Mean	SD	W/in SD[a]	ICC[b]	% None[c]
Trait Control					
Personal Mastery	5.71	1.04	-	-	-
Perceived Constraints	2.56	1.14	-	-	-
Event-Specific Control					
All Events	1.45	0.51	1.11	0.31	36%
Interpersonal Tensions	1.78	0.60	0.98	0.38	22%
Overload Stressors	1.33	0.63	1.04	0.38	38%
Network Stressors	0.47	0.50	0.77	0.39	74%

[a] Within-person standard deviation.

[b] Calculated by SD/(W/in SD + SD).

[c] Frequency of reporting "none at all" for each stressor type.

Table 4. Trait Control Predicting Daily Perceived Control.

	Model 1		Model 2	
	Est.	SE	Est.	SE
Intercept	1.44	0.025	1.44	0.212
Personal Mastery			0.056*	0.028
Perceived Constraints			-0.119***	0.026
Residual Variance	1.23	0.033	1.22	0.033
Between Variance	0.26	0.029	0.23	0.028
Psuedo R Squared			0.12	

*** p<.01; *p<.05.

Table 5. Trait Control Predicting Stressor-Specific Perceived Control

	All	Int. Tensions	Overloads	Network
Intercept*	1.44** (.025)	1.77** (.03)	1.32** (.04)	0.465** (.05)
Personal Mastery		0.144** (.03)	0.15** (.04)	0.02 (.04)
Perceived Constraints		-0.184** (.03)	-0.15** (.03)	-0.02 (.04)

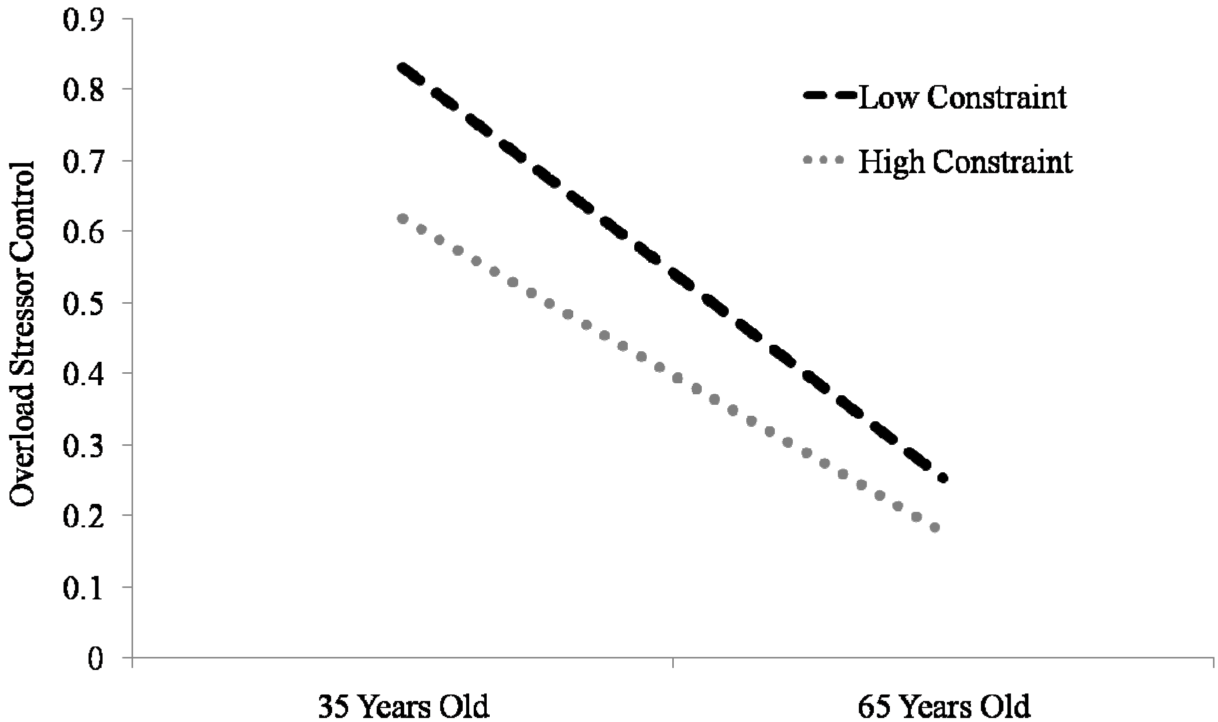
* Est. (SE); ** p<.01; *p<.05.

Table 6. Moderation Between Trait Control and Daily Perceived Control.

	All	Int. Tensions	Overloads	Network
Intercept*	1.44*** (.025)	1.77** (.03)	1.32** (.04)	0.465** (.05)
Personal Mastery		0.144** (.03)	0.15** (.04)	0.02 (.04)
Age		0.001 (.03)	0.000 (.003)	0.013** (.03)
Gender		-0.17** (.07)	-0.23** (.08)	0.01 (.09)
Education		0.013 (.04)	0.08** (.05)	0.006 (.05)
Perceived Constraints		-0.184** (.03)	-0.15** (.03)	-0.02 (.04)
Age		-0.001 (.002)	-0.002 (.003)	0.013** (.004)
Gender		-0.14* (0.07)	-0.22** (.08)	0.012 (0.09)
Education		-0.24 (0.36)	0.06 (.05)	0.003 (.05)
Age*Constraint		.000 (.002)	.006* (.003)	.001 (.003)

Est. (SE); ** p<.01; *p<.05.

Figure 1. Interaction between Perceived Constraint and Age on Overload Stressor Control



CHAPTER III

THE FEASIBILITY OF AND CONSIDERATIONS FOR COLLECTING SALIVARY CORTISOL IN A NATURALISTIC SETTING

Introduction

Cortisol has captured the attention of many social scientists interested in the effects of stress on health. While cortisol has been studied in laboratory settings for over 100 years, recent advances in collection and assay technologies have allowed investigators to measure salivary cortisol in more naturalistic settings. Cortisol is a hormone regulated by the hypothalamic-pituitary-adrenal (HPA) axis and is commonly referred to as the "stress hormone" because of heightened secretion in the physiological response to stressful events (Dickerson & Kemeny 2004; Nicolson, Storms, Ponds, & Sulon, 1997). Cortisol is not only secreted in response to stressors however; a natural quantity exists in healthy humans and animals alike (corticosterone in animals) as the main function of cortisol is to mobilize energy. Cortisol secretion also follows a distinct circadian rhythm. Shortly after awakening in the morning, there is a sharp upward spike, typically occurring 30 to 45 minutes after awakening in which cortisol increases by 50-75% (Ranjit, Young, Raghunathan, & Kaplan, 2005). This increase has been shown to be independent of morning wake time, sleep hours, and sleep quality (Wust, Wolf, Hellhammer, Federenko, Schommer, & Kirschbaum, 2000). Soon thereafter, there is a steep decline in the next few hours, and a steady decline throughout the day until the nadir period occurs, sometime during sleep hours (Ranjit, Young, Raghunathan, & Kaplan, 2005; Hruschka, Kohrt, & Worthman, 2004).

Because of the hormone's responsiveness to stressful stimuli, salivary cortisol is often studied as an outcome in the stress process where researchers introduce a stressor and measure the participant's physiological reactivity. Cortisol has almost exclusively been studied in strictly controlled settings with relatively small sample sizes. While these studies have been invaluable to the advancement of understanding the physiological response to stress processes, the ecological validity of the assessments is questionable. The assessment of cortisol in the context of more naturally occurring contexts, however poses numerous challenges that threaten the reliability and validity of the assessment of cortisol.

The goal of the present study is to describe the feasibility of collecting diurnal cortisol in a naturalistic setting. The major challenge to field studies of salivary cortisol is the lack of control over the cortisol collection. This paper describes considerations for maximizing compliance and increasing the validity of salivary cortisol assessments. In doing so, four sources of error are addressed that represent potential problems or “flags” for researchers wishing to study cortisol outside of a laboratory setting. These four sources of error occur on days during which: 1) individuals are awake for longer or shorter time periods than typical, 2) individuals awaken at odd hours of the day, 3) individuals have abnormal cortisol patterns most likely due to noncompliance, and/or 4) individuals do not provide their salivary cortisol sample at the proper time. After discussing methods for operationalizing the measurement of cortisol, this paper will assess the validity of collecting salivary cortisol in a naturalistic setting by comparing results to studies with more investigator control. The final goal of the present study will be to compare how results are affected by including and not including cortisol flags in analyses.

Field Studies Collecting Salivary Cortisol

There has been a recent surge in research studies in which investigators have collected salivary cortisol outside of laboratory settings. While the focus of these studies has not necessarily been on the stress process, many studies are taking advantage of advances in salivary collection technology. A recent review article has been helpful in summarizing research documenting variation in salivary cortisol measured in field studies (Hansen, Garde, & Persson, 2008). Outside of the laboratory setting, variation in salivary cortisol has been attributed to seasons (King, et. al. 2000), age (Nicolson, et al., 1997; Seeman et al., 2001); gender (Schultz, Kirschbaum, Prussner, & Hellhammer, 1998; Hansen, et al., 2003), diet (Gibson et al., 1999), medications (Hellhammer, et al., 2004; Hibel, Granger, Kivlighan, & Blair, 2006), alcohol (Beresford et al., 2006; Adinoff et al., 2003), smoking (Badrick E, Kirschbaum C, Kumari, 2007; Steptoe & Ussher, 2006), and physical activity (Frey, 1982; Kirschbaum & Hellhammer, 1994).

In addition to the previous research, one field study obtaining salivary cortisol specifically measured compliance of participants (Broderick, Arnold, Kudielka, & Kirschbaum, 2004). Participants in this study were instructed to provide 5 saliva samples at specific times across 7 consecutive days. Half of the participants were informed that their saliva samples were monitored for compliance and the other half were not. Results revealed that 71% of those participants who were ignorant of monitoring and 90% of those who were informed of the monitoring were compliant with saliva collection protocol. Self-reported compliance rates were 90% and 93%, respectively, for the two groups (Broderick, et al., 2004).

Advantages of Salivary Cortisol

Cortisol has become quite popular in both the biobehavioral and psychological stress literature because of its advantages as a biomarker of stress. The objectivity of cortisol as an indicator of health in stress research is not a new concept. Methodological innovations have made salivary cortisol collection a viable option for interested researchers, however, whereas in years past it was only possible to assay cortisol in samples of plasma or urine.

Cortisol can be measured in both the blood and urine between 15 and 70 minutes after a stressor (Baum & Grunberg, 1997). Today, one advantage of using cortisol as a reactive measure of stress is that it can also be obtained through saliva. After cortisol is released, it can be detected in saliva after 5 minutes. Technological advances in assay technology and the introduction of salivettes (Sarstedt Inc.) have allowed researchers to collect cortisol relatively unobtrusively and rather inexpensively. Because of these advancements, it is now possible to obtain saliva samples from participants without the need of laboratory supervision. Studies have found correlations between plasma, urine and salivary cortisol from .71 to as high as .96 (Kirschbaum & Hellhammer, 1994).

Utilizing salivary collection methods makes it easier for researchers to obtain cortisol without face-to-face interaction with their participants; however, there are some differences between cortisol obtained through saliva versus plasma or urine (Meulenberg & Hofman, 1990; Kirschbaum, et al., 1999; Putignano, et al., 2001). Salivary cortisol is “free” or “unbound” which means 95% of the circulating cortisol in the blood is bound to cortisol binding globulin (CBG). Only the molecules that are not bound to CBG (i.e. the unbound) can diffuse through the salivary glands and enter the saliva (Dickerson & Kemeny, 2004). Cortisol measured in plasma or urine contains both bound and unbound/free cortisol, while saliva contains only unbound cortisol.[1]

Many methods of cortisol collection, such as salivary collection, are relatively unobtrusive and therefore increase opportunity for participation in such studies. In addition, these options are becoming less expensive, allowing more researchers to collect such data (Hibel, Granger, Kivlighan, & Blair, 2006). Furthermore, cortisol is durable in that it does not need to be immediately frozen in order to detect it in the saliva. In fact, even when stored at or above room temperature for as long as 16 weeks, there is not a significant reduction in the amount of

[1] Additionally, the scales measured in the two techniques are different. In plasma and urine collections, cortisol is typically measured in micrograms per deciliter (ug/dL), whereas in saliva, cortisol is measured in nanomoles per liter (nmol/l). The conversion to nmol/l = ug/dL x 27.59.

detectable cortisol in saliva (Kirshbaum & Hellhammer, 1989). Finally, due to the predictable circadian rhythm in cortisol, collection of many (i.e. more than 10) data points throughout the day may be inefficient and unnecessary depending on the aims of the study.

Challenges of Salivary Cortisol

As previously noted, there are many advantages of using salivary cortisol as a biomarker in stress research. There are, however, some limitations. Although a naturally occurring amount of cortisol is present in all individuals, basal concentrations of cortisol can be problematic due to daily variability in secretion. Therefore, for reliability purposes it is most efficient to utilize multiple days of collection. In a similar vein, many studies have documented the responsiveness of cortisol to stressful situations, but there are mixed results concerning the duration of this increased response as well as the return to baseline. Following laboratory-induced stressors, peak cortisol response occurs between 21 and 45 minutes after the onset of the stressor (Dickerson & Kemeny, 2004). Both age and health status seem to be related to how long it takes for an individual to return to their baseline measures following a stressful event (Kudielka, Buske-Kirschbaum, Hellhammer, & Kirschbaum, 2004). Older individuals and individuals in poorer health are slower to return to their baseline values. In both cases, this could very well be due to the phenomenon of allostatic load, whereby as physiological systems are called upon to repeatedly react to stressful events, these systems begin to wear down (McEwen, 1998). Therefore, if the goal of stress research is to examine specific response in cortisol reactivity it would be necessary to obtain collections both before and very soon after a stressor occurred. In naturalistic field studies this might not be feasible. It might be more fruitful to investigate broader parameters of cortisol reactivity in order to maximize cost-effectiveness and minimize participant burden.

While some strengths of cortisol are the predictability of the circadian rhythm and the ease of collection via saliva, many factors other than stress can influence the levels detected. These factors include, but are not limited to, caffeine, medications such as oral contraceptives, other hormones, allergy medicine, and menstrual cycle phase (Kirschbaum & Hellhammer, 1994; Kirschbaum et. al, 1999). It is therefore imperative to obtain detailed information about all medications respondents have taken on days when they provide saliva samples. In addition, participants should be instructed not to consume certain foods prior to providing samples.

One final limitation of collecting salivary cortisol is the concern over the ability to extract cortisol from the salivette. Granger and colleagues (2007) conducted a study comparing 4 salivary collection techniques and compared the amount of cortisol extracted from each. The study found that the amount of cortisol extraction varied depending upon the method of collection used (salivette v. cotton rope v. hydocellulose microsponge) and the amount of saliva in the initial collection (Harmon, Hibel, Rumyantseva, Granger, 2007). The most important thing to note here is that differences measured between cortisol measured via saliva versus other means could be a function of the assay itself. One way to control for this is to assure that the collection method is uniform across all study participants. The present study accounts for this by using standard salivettes (Sarstedt Inc.) for all participants in the study. In addition, many studies have validated the use of salivettes in field studies of salivary cortisol (Kirschbaum & Hellhammer, 1994; Shirtcliff, Granger, Schwartz, Curran, 2004; Polk, Cohen, Doyle, Skoner, & Kirschbaum, 2005).

Operationalizing the Measurement of Cortisol

As previously mentioned, secretion of cortisol follows a distinct circadian rhythm characterized by a quick rise in the morning and a gradual decline throughout the rest of the day.

Figure 2 depicts this pattern. Due to the circadian rhythm of cortisol, researchers wishing to utilize the hormone as an outcome in stress studies cannot rely on single measurements during a daily cycle (Dickerson & Kemeny, 2004) and must collect it at multiple time points during a day. As a consequence of this practice, investigators have established methods of characterizing the measurement parameters of cortisol. The following section highlights different methods of operationalizing the measurement of cortisol in biopsychosocial research.

Salivary cortisol is usually expressed on one of two scales as either nanomoles per liter (nmol/l) or micrograms per deci-liter (µg/dl). When operationalizing the measurement of salivary cortisol, researchers often transform the raw values by taking the natural log (ln) in order to normalize the distribution. Logged values of cortisol can be useful in describing sample characteristics, especially when examining peak and low points during the day (Ranjit, et. al, 2004; Hruschka, et. al, 2004). The simplest method of operationalizing the measurement of cortisol across a day is to calculate a daily average of the logged values by adding up the values and dividing by the number of collection points. One problem with this method is the inability to account for intraindividual variation in cortisol levels throughout the day. Another limitation of aggregation across the day is that averages ignore the "possibility that a variable may have different effects at different times of day" (Hruschka, et. al, 2004; p. 700).

As previously mentioned, a common practice in operationalizing the measurement of cortisol is to take its natural log in order to obtain normally distributed scores. There is an important methodological consideration about calculating area under the curve (AUC) if researchers wish to use the natural log of cortisol to transform their data. When transforming cortisol values between 0 and 1, the result will be a negative number. Since AUC is essentially calculated by multiplying cortisol values as a function of the time they were taken, if any one value is negative, then the AUC value will also be negative. In order to address this concern, researchers can add a constant value before log transforming. The present study added "1" to raw cortisol values before log transforming.

Insert Figure 2 about here

Cortisol Awakening Response (CAR). As depicted in Figure 2, the circadian rhythm of cortisol can be parameterized into two distinct pieces, cortisol awakening response (CAR) and daily decline. CAR is an indicator of how high an individual's cortisol spikes at its peak. An individual must provide a saliva sample immediately upon awakening and a second collection 20-45 minutes after in order to capture this portion of the circadian rhythm (Wust, et. al, 2000). Healthy individuals typically show a positive (increasing) slope for CAR. As a proxy for health, the cortisol awakening response could be an indication of an individual's ability to physiologically prepare for challenges of the day. In addition, negative health consequences are often encountered when individuals show low CAR (Brandtstädter , Baltes-Gotz, Kirschbaum, & Hellhammer, 1991). In a meta-analysis of 509 adult subjects, 23% of the participants providing saliva samples did not show an increase in cortisol following awakening (Wust, et. al, 2000). In this study, many factors had no association with the CAR including age, total sleep time, and use of oral contraceptives. Wust and colleagues did show one interesting gender effect where females had a longer rising period. On average, males' cortisol started to decline within 30 minutes after awakening, whereas females showed a delayed decrease resulting in longer CARs and higher AUC values (Wust, et. al, 2000).

Daily Decline. The second piece in Figure 2 is “daily decline” and refers to the difference between the high point soon after awakening and the final data point in the day when cortisol levels reach their lowest level just before sleep. As a parameter, daily decline represents an individual’s ability to regulate cortisol throughout the day (Ice, Katz-Stein, Himes, & Kane, 2004). In healthy individuals, the daily pattern should have a negative slope. Overactivation, or a slope closer to zero, is hypothesized to represent one of two possibilities. The first could be a physiologic reaction to an event encountered during the day (Kudielka, et. al, 2004); however, even when experiencing a stressful event, individuals should only show increased cortisol levels for a brief period of time. Laboratory studies involving stress-inducing task, on average have shown cortisol levels returning to baseline within one hour following the stressor (Dickerson & Kemeny, 2004). A second possibility could represent dysregulation of the HPA-axis, a potential consequence of chronic activation. This has been hypothesized to be an indication of chronic stress such as with caregivers or chronic work strain (Cohen et. al, 2006). To date, it has been difficult to determine whether abnormalities in cortisol circadian rhythm are a sign of maladaption or if a certain portion of the population normally has unusual patterns. Stone and colleagues (2001) found that even a proportion of healthy individuals have flat patterns. In this study, 51% of respondents showed “normal” circadian patterns, 17% had flat cycles, and the remaining 34% show inconsistent cycles (Stone, et. al, 2001).

Cortisol awakening response and daily decline parameters can be estimated with the use of multilevel models in studies where multiple cortisol samples are collected on multiple days (Hruschka, et. al, 2005). Using a three-level MLM approach, occasions throughout the day (level 1) are nested within days (level 2) which are nested within individuals (level 3). A piecewise model allows for individual estimation of both the CAR (piece 1) and the daily decline (piece 2; a review of the formulas and methods of calculating these pieces can be found in Hruschka, Kohrt, & Worthman, 2005).

Area Under the Curve (AUC). A slightly more complex method is to calculate the "area under the curve" (AUC). Figure 2 highlights the area defined in this parameter. In order to measure this parameter, one must plot an individual's daily cortisol points and calculate the geometric area below the individual's line. AUC is often used in "endocrinological studies to estimate the changes of hormones" (Pruessner, et. al, 2003; for formulas on calculating AUC, please refer to this article). Area under the curve represents the total concentration of an individual's cortisol throughout the day. Another method of examining daily cortisol, as mentioned above, is to simply take the average level of cortisol for an individual across a day; however, an average only gives a brief snapshot of daily cortisol. One advantage of AUC over a daily average is that AUC takes into account intraindividual variation. For example, an individual with a sharp morning spike and a steady daily decline might have a daily average equal to another person who has elevated levels of cortisol with no variation. The two individuals' daily averages ignore the circadian rhythm that is captured by AUC.

"Flags" for Utilizing Salivary Cortisol

Four issues must be addressed in order to obtain an accurate depiction of the diurnal pattern of cortisol. For each of these issues, the problem will first be described followed by a discussion of how it biases the population average of the diurnal rhythm. Each section will end with a recommendation on how to remedy the problem before performing analyses on a cortisol dataset. Refer back to figure one for a depiction of the prototypical diurnal rhythm of cortisol.

Flag 1: Awake Less than 12 or More than 20 hours (N = 109 or 2.4% of days)

The first cortisol flag describes days when individuals are awake for an atypical amount of time. This includes days where individuals are awake for less than 12 hours or days when individuals are awake for more than 20 hours. This potentially biases the daily decline parameter by missing the putative nadir of the daily decline. In either case, we would expect an individual's final cortisol time point to be higher than expected had they had a normative sleep pattern on that day (refer to Figure 3). In the results section, this hypothesis is tested. If this is indeed the case, the suggestion for the day would be to drop the final cortisol collection point, and thus not include the daily decline parameter.

Insert Figure 3 about here

Flag 2: Wake Past Noon (N = 34 or 0.75% of days)

Another potential problem with naturalistic cortisol measurement occurs on when individuals report waking up after 12:00 pm. This becomes problematic because of an asynchrony with natural light-dark cycles. A day where an individual works a night shift would be an example of this occurrence (see Figure 4). Potentially, one could see the exact same rise and fall of cortisol as in a "normal" sleep pattern day, but in a condensed period of time; however, there is also the possibility that the rise and peak point of cortisol would be much lower than expected compared to days when individuals wake at a more typical hour. Because these days are rare, and represent a complete anomaly from typical patterns, the suggestion would be to exclude the entire day of cortisol data on days when this problem occurs.

Insert Figure 4 about here

Flag 3: High Lunch Time Cortisol (N=63 or 1.39% of days)

The third cortisol flag occurs on days where an individuals' lunch time cortisol collection is their highest point in their day. Researchers should be cautious when flagging a day because of this occurrence. Cortisol may rise at various points throughout the day for a variety of reasons (e.g., if an individual experiences a stressful event, becomes ill, takes medication, etc.) The present study operationalizes "higher" lunch time cortisol as being 10 or more nmol/l higher than the second collection point (which should be an individual's highest point) of the day. Data from the present study show that on days when lunch time cortisol was an individual's highest point, participants were not more likely to have higher negative affect, experience a stressful event, take medications, or work longer hours. Figure 5 shows actual data for an individual on all 4 days of cortisol collection. For this individual, not only was lunch time cortisol the highest point on day 3, it was actually higher than any other point on any of the 4 days. Because there are no variables explaining this occurrence, the best hypothesis is that this flag represents non-compliance with the instructions given to the participants. One explanation for this phenomenon could be an individual accidentally switching their morning and lunch samples on a given day. Alternatively, eating lunch, consuming caffeine, or taking medication can all affect one's cortisol. Participants were instructed to provide a saliva sample before doing any of these activities at lunch time. It therefore makes sense that the most practical option for these days is to exclude the daily decline estimate from analyses.

Insert Figure 5 about here

Flag 4: Post-wake (Time 2) Assessment Provided at Wrong Time (N = 414 or 9.12% of days)

The final cortisol flag occurs on days when a participant fails to provide the second daily sample when instructed. Recall, an individual's cortisol rises to its daily peak between 30 and 45 minutes after waking. This flag represents days when individuals report providing their sample either too soon (less than 15 minutes) or too long (more than 60 minutes) after their initial sample. This represents a problem because the second time assessment is used to calculate both the CAR and daily decline parameters for the day. If the saliva sample is not obtained at the correct time, then the individual's peak cortisol point is not captured for that day. Figure 6 represents an example of cortisol data on a day when an individual fails to provide their second sample at the correct time. Depending on when the sample is provided, the estimate of the CAR (if given too early) or the estimate of the daily decline (if given too late) will be lower than expected. At this time, the best suggestion to deal with this problem is also to exclude the entire day of cortisol data.

Insert Figure 6 about here

The Present Study

The present study addressed the feasibility of collecting cortisol using naturalistic methods in a nationally representative sample. Because the nature of naturalistic data collection implies fewer controls, it is expected that investigators will face challenges not seen in laboratory settings while collecting saliva samples from study participants. These issues were addressed by comparing results from the present study to the findings of previously published studies in which investigators had more control over their sample. The present study established that individuals will participate in studies in which they are expected to provide multiple saliva samples on multiple days. More important then simply providing samples, results also provided evidence that individuals can be compliant with saliva collection protocol and provide valid results. It is with this in mind that the present paper presents the following research questions.

Research Questions

1. The four flags described above present challenges to researchers working with cortisol. What is the prevalence of these flags in a nationally representative sample of older adults, providing saliva samples on 16 occasions across 4 days?
2. By utilizing saliva samples provided at various points in the day, researchers may examine the diurnal pattern of cortisol. How will these flags affect the parameters of the diurnal rhythm of cortisol? In addition, how are individual occasions of cortisol measurement affected by the four flags?
3. The methods used in the current study allow for the assessment of the validity of cortisol data collected in a naturalistic setting. How will results for the present study compare to previously published findings based upon salivary cortisol data in which investigators had more control over their participants' behavior and the saliva collection protocol? Will diurnal parameters of cortisol be similar for these two types of studies?

Method

Participants

Participants for the present study come from the initial set of respondents participating in the second wave of the National Study of Daily Experiences (NSDE, N = 1,265). Participants for the NSDE come from a subsample of the National Survey of Midlife in the United States

(MIDUS), a nationally representative telephone-mail survey of 4,963 people aged 35-84 years, conducted in 2003-2004, under the auspices of the MacArthur Foundation Research Network of Successful Midlife Development. Participants in the NSDE completed short telephone interviews across eight consecutive evenings about their daily experiences. The current response rate for the study is 76% with a retention rate of 96%. On average participants provided a mean of 7.5 interviews per 8 days (summing to a total of 10,120 interview days). For the current analyses, only those participants who agreed to provide saliva samples were included (N = 1,143; 90 %).

Recruitment and Interview Procedure

Approximately one week before telephone contact, participants received a package containing a recruitment letter and a summary of previous findings, a check for $25, as well as a “Home Saliva Collection Kit”. The kit contained instructions for saliva collection, a “Home Collection Sheet” for documenting the times samples were collected, 16 salivettes, a self-addressed UPS bio-hazard package with pick up instructions, and finally a stress ball as a token of appreciation for participating in the study.

Approximately one week after recruitment mailing, an initial call was made to participants requesting their participation in the study. The daily telephone interview consisted of questions about daily activities (including social support), physical symptoms, alcohol and tobacco use, negative and positive affect, productivity, in-depth assessment of stressors, positive events, medications, and a weekly review (on day 8 only).

Saliva Collection

In addition to the daily telephone interview, participants were instructed to provide saliva samples on days 2 through 5 of the study, at 4 time points throughout the day: immediately upon awakening, 30 minutes after awakening, before lunch, and before bed, for a total of 16 samples (4 times on 4 days). The directions instructed participants to provide saliva samples at least 1 hour before eating, drinking, consuming caffeine, or brushing their teeth. Upon completion of the collection, participants were instructed to arrange for the kit to be picked up by UPS.

Saliva Statistics

Of the 1,265 respondents, 1,143 provided saliva samples (90%). Of the 18,288 possible samples (1,143 x 16 samples), there were 546 missed samples or samples with insufficient volume to detect cortisol (~ 3%). A small portion of samples yielded cortisol data considered out of range (i.e. above 120 nmol/l; 305; < 1%). These data resulted in final cortisol analyses based on 96 % usable samples (N = 17,465 samples).

Comparison Studies

In an article by Stone and colleagues (2001) the authors examine 4 studies in which participants provided salivary cortisol. All four studies collected salivary cortisol at various occasions throughout the day on multiple days; however, the four studies differ in their sample characteristics as well as the number of days and occasions within a day for saliva collection. Described below is all of the published information about the four studies.

Kirschbaum study 1 – 66 participants, 25 saliva samples collected, on 1 day. A total of 25 saliva samples were taken by each participant at 30 min intervals between 9 am and 9 pm. The samples were collected in the study laboratory with the supervision of a lab technician.

Kirschbaum study 2 – 20 participants, 49 saliva samples per day, across 2 days. The sample for this study consisted of 10 healthy male smokers and 10 healthy male nonsmokers. The average age for the sample was 25 years. On two consecutive days, participants collected saliva samples at 15-min intervals between 9 am and 9 pm.

Cohen – 176 participants, 9 saliva samples per day, across 2 days. The sample consisted of healthy adults between the ages of 18 and 55 years. The average age was 29.6 (SD = 10.7) years. All participants were given instructions on the protocol for collecting saliva and their samples were collected in the participants' natural settings. Samples were collected across 2 consecutive days at the following 9 occasions: at wake-up, and 1, 2, 4, 6, 8, 10, 12, 14, and 16 hours following wake-up. Participants in this study were provided a preprogrammed wristwatch that alerted the subject when it was time to provide a saliva sample. 53% of the participants were males, 65% were Caucasian, and 56% had completed at least some college.

Smyth – 49 participants, 3 saliva samples per day, across 24 days. The sample consisted of 49 patients with Rheumatoid arthritis. Saliva samples were provided at randomly selected times in the morning, afternoon, and evening when patients were signaled via a preprogrammed wristwatch to take a saliva sample, yielding a maximum of three saliva samples per day. The average age of the participants was 51 years, 71% were female, 96% were Caucasian, and the average education was 14.1 years.

Another study (Wust, 2000) collected saliva data to specifically investigate the cortisol awakening response and will be utilized as a comparison for the current study.

Wust – 509 participants across four studies, 4 saliva samples per day, across 2 days. This paper reported combined statistics from four independent studies. Samples were collected by the participants in their home on two consecutive days. Participants were instructed to provide samples at 0, 30, 45, and 60 minutes after awakening each day. Participants were also instructed not to brush their teeth before providing samples and not to smoke or eat within 10 minutes prior to providing a sample. Across the four studies, all participants reported they were in good health, 63% were female, and 28% of the females were using oral contraceptives.

Multilevel Modeling

Multilevel modeling was used to estimate parameters of daily cortisol. Recall, the CAR represents an individual's ability to physiologically prepare for the day, the daily decline represents the individual's ability to physiologically shut down for the day, and AUC represents the total concentration of salivary cortisol. In these models, three levels were utilized: occasions, days and individuals. Occasions are nested within days and days nested within individuals. The following equations describe this three level model

$$L1: Cort_{odi} = \beta_{0di} + \beta_{1di} MR_{1odi} + \beta_{2di} DD_{2odi} + r_{odi}$$

where cortisol on a given occasion (o), on a given day (d), for a given individual (i) is a function of an individual's baseline measure (or intercept, β_{0di}) , plus that individual's slope for their CAR for that occasion on that day ($\beta_{1di} MR_{1odi}$), plus their slope for daily decline at that occasion on that day ($\beta_{2di} DD_{2odi}$), plus random fluctuation around their level (error). At level 2 the outcomes are the daily parameters of circadian rhythm of cortisol:

$$L2: \beta_{0di} = \delta_{00i} + U_{0di}$$

$$L2: \beta_{1di} = \delta_{10i} + U_{1di}$$

$$L2: \beta_{2di} = \delta_{20i} + U_{2di}$$

where the intercepts and slopes on each day are modeled as a function of the mean for each individual plus an individual's deviation from their own mean across the four days. At level 3 the outcomes represent the mean of the circadian parameters across the four days for each individual.

$$L3: \quad \delta00i = \gamma000 + V00i$$

$$L3: \quad \delta10i = \gamma100 + V10i$$

$$L3: \quad \delta20i = \gamma200 + V20i$$

Within person slopes for daily cortisol levels were estimated using a piece-wise (spline) model such that piece one represented the CAR and piece two represented the daily decline. Step one was to "stack" the data in a person-day-occasion file such that each row represents one occasion on one day for one individual. Therefore, each person will have 16 rows (one row representing each occasion that saliva is collected). An example of the data set up has been included for one participant in Table 7.

Insert Table 7 about here

All multilevel models were conducted using the PROC MIXED command in SAS (v. 9.0). Intraclass correlations (ICC) were calculated by running a model with perceived control as the dependent variable and no predictors (empty model).

Results

The first research question addresses the prevalence of the four cortisol flags. A summary of the flags is provided in Table 8. Flag 1 (awake for less than 12 or more than 20 hours) occurred on 109 (2.4%) days, Flag 2 (waking past noon) occurred on 34 (0.75%) days, Flag 3 (lunch cortisol value highest in day) occurred on 63 (1.39%) days, and Flag 4 (2^{nd} assessment provided at incorrect time) occurred on 414 (9.12%) days. Combining all flags resulted in individuals having any flag on 552 (12.15%) days. If only flags 1 through 3 were included, the result would be a flag on 179 days (3.94%).

Insert Table 8 about here

The second research question for the present study addresses how the four flags will affect the diurnal rhythm of salivary cortisol. Table 9 summarizes these effects for the intercept, CAR, daily decline, and area under the curve for daily cortisol.

Insert Table 9 about here

The first row of Table 9 represents all 4,521 days where saliva samples were provided, without accounting for any cortisol flags. The three cortisol parameters: cortisol awakening response (B = .297, SE = 0.02) daily decline (B = -.116, SE = 0.00), and AUC = 88.49, SE = 0.46 are reported. Rows 2 through 5 (Flags 1 – 4) represent days during which all of the four flags occurred. The second to last row, "CortFlag = 1" represents days on which any of the four flags occurred. Finally, the last row, "CortFlag = 0" represents all remaining days after each of the four flags were dropped from the analyses, CAR (B = .300, SE = 0.02) daily decline (B = -.119, SE = 0.00), and AUC = 87.96, SE = 0.46 are also reported.

Intraclass correlations (ICC) are also reported in Table 9. The percentage reported shows the amount of between-person variability for the estimate. An estimate of 50% means that an individual is just as likely to vary from themselves from day to day(within-person variability) as they are to vary from another individual (between-person variability). For example, when accounting for no flags (first row), the ICC for the daily decline was roughly 42%. This means that 42% of the variability in daily decline is between-person, and the remaining 58% of the variance is within-person. When accounting for all four flags, the ICC in daily decline drops to 31%, which means that 69% of the variance in daily decline is within-person.

The final research question addressed the validity of salivary cortisol collection in a naturalistic setting. Accordingly, the final goal for this study was to assess whether cortisol data collected in this naturalistic manner and utilizing a national sample would show similar circadian rhythms when compared with results of previously published studies with smaller samples or in more controlled research settings.

Insert Table 10 about here

Wust and colleagues (2000) combined four independent studies that assessed cortisol secretion several times following waking in the morning. Table 10 compares the present study's cortisol values to the findings presented by Wust et al. (2000). As shown, mean cortisol levels across studies in the Wust et al. article are similar for both waking cortisol and cortisol measured 30 minutes after awakening. As one would expect, in a nationally representative sample with fewer experimental controls, such as in the NSDE, standard deviations are larger.

In a similar manner, Table 11 compares the slope of daily decline in the four studies reviewed by Stone and colleagues with those of the NSDE study. These studies differed on the number of participants, number of saliva collections throughout the day, as well as number of days saliva was collected.

Insert Table 11 about here

Despite the differences between these four studies and the NSDE, results are similar across the four smaller studies and when compared with the NSDE. Mean level slope of daily decline is only slightly higher in the NSDE and again, as expected due to the nature of the present study, standard deviations are also higher.

Similar to the previous table, Table 12 compares the same four studies to the NSDE on the bottom and top quintiles of the slope of daily decline in cortisol levels. As shown, the bottom 20% of the NSDE falls within range of the four studies and the top 20% of NSDE participants' daily decline slopes are again only slightly higher than participants whose saliva was collected in a naturalistic environment under more stringent controls.

Insert Table 12 about here

Discussion

The goal for this paper was to describe issues that researchers can expect to encounter when collecting salivary cortisol in a field study and, after accounting for these issues, to validate the parameters of cortisol data collected in this manner against previously published papers. Four flags were described that could potentially bias estimates of the diurnal rhythm of cortisol. Combining the four flags in an "any flag" variable resulted in participant's having at least one flag on 552 out of 4,521 days (12.15%). Even after utilizing the most conservative approach by selecting out these days in analyses, over 87% of saliva collection days were still analyzable.

The second research question addressed how accounting for cortisol flags would change estimates of the parameters of cortisol. Estimates calculated only on flag days dramatically changed the parameters. For example, CAR was highest on days where individuals' lunch time cortisol was the highest point (Flag 3; $\beta = .72$), and daily decline was the least steep on days where individuals awoke after 12:00 noon (Flag 2; $\beta = -.029$); however, when comparing estimates without accounting for flags (i.e., removing flagged days from analyses), the differences are less substantial. The slope for CAR rose by .003, less than a 1% increase; the daily decline slope went down (i.e. became steeper) by .003, a 2.5% decrease, and AUC decreased by .53, less than a 1% decrease.

While accounting for cortisol flags is important, these flags occurred only on a small percentage of days in the current study. Even after excluding all flagged days from the analyses, there were still over 15,000 cortisol samples utilized. Excluding days with flags in a study with a smaller sample may result in more dramatic changes. In addition, the difference in the ICCs between these two analyses must be taken into account. Within-person variation in the daily decline slope rose from 58% to nearly 70% after accounting for the cortisol flags. Researchers interested in day-to-day fluctuations in the diurnal rhythm of cortisol would want to estimate these parameters as accurately as possible, making the flags an important consideration.

The final research question addressed the validity of collecting cortisol in a naturalistic setting, without face-to-face instructing of the participant. By comparing results from the present study with results from previously published papers, there is evidence that individuals are not only willing to participate in research in which they must provide saliva samples, but they can do so reliably and provide valid results. Comparing the morning estimates of the current study with those of the Wust et al. (2000) study resulted in less than a 1 nmol/l difference in both waking cortisol and the 30 minute post-waking sample. Additionally, there was a less than .03 difference in the daily decline slope between the current study and the four papers discussed by Stone et al. (2001). This held true for the entire sample as well as slopes on the extreme ends of the distribution. Researchers wishing to utilize saliva samples to assay cortisol should find these results very promising.

Data from the current study utilized one of the largest cortisol samples ever collected in terms of saliva samples provided. This is one of the major strengths of the study. The current study utilized the initial set of respondents (N = 1,143 participating in saliva collection), and the final data set will include over 1,800 individuals providing saliva samples at 4 occasions on 4 consecutive days, which will result in nearly 30,000 saliva samples. This will allow future studies to compare the results with a national sample for expected parameters of the diurnal rhythm as well as frequency of flags, missing samples, and samples with insufficient data.

A second strength of the study is how parameters of cortisol are estimated using multi-level models. The diurnal rhythm is estimated based on the exact time participants provided their samples. Participants were not instructed to provide samples at specific times, such as "at 8:00am", rather they were instructed to give a sample "immediately upon waking" or "just before lunch". This allows participants to be flexible and provide samples based on their schedule. This protocol was designed specifically to increase participant compliance and to reduce missed samples.

The study's methodology allows more individuals to participate because they do not have to be face-to-face with researchers. While this methodology may result in greater participation, it also contains inherent limitations. One of the limitations of this method is not having exact control over when participants provide samples, either at specific occasions or on specific days. The present study attempts to combat this limitation using various techniques. First, participants are provided with a Home Collection Sheet on which they document the date and time that each sample is provided. The Home Collection Sheets are then returned and the dates and times are verified with the dates and times provided by the participants in the daily phone interviews.

Preliminary analyses indicated that participants' dates did not match the date they were expected to provide salivary cortisol samples on 63 occasions (less than 1%).

An additional check on participant compliance was conducted on a subsample of individuals who were provided with a "smart box", which has a microchip that records the date and time the box was opened. Participants were instructed to leave their salivettes in the box until it was time to provide the saliva sample. Future analyses will include data on this subsample to further investigate compliance.

Compliance was the main concentration in preparing the methodology for the current study. One of the limitations of the recommendations provided herein regarding methods for accounting for cortisol flags is the amount of data that may potentially be removed from analyses. After accounting for cortisol flags, excluding 552 samples leaves the current study with over 15,000 samples remaining for analyses; however, for a smaller study, excluding a large number of samples may not be feasible.

One way to combat this limitation is for future studies to include more samples in the morning. For example, in the current study, if the participant does not provide a second sample within 1 hour of awakening, the cortisol awakening response cannot be accurately estimated. If participants were instructed to provide a sample 15 minutes and 30 minutes after waking up, this would result in capturing the CAR even if participants are 30 minutes late on both samples. This would result in fewer occasions in which this diurnal parameter is not possible to estimate due to missing or unreliable data.

In addition, future studies may benefit from methodology described in some of the comparison studies, which utilized wristwatch alarms to remind the participants when it was time to provide a sample (Cohen, et al., 2006; Smyth et al., 1997). Furthermore, the current study utilized a heterogeneous sample, including some individuals who may have been shift workers and thus having atypical cortisol diurnal rhythms. Future studies may wish to screen out participants who have atypical schedules that might confound cortisol diurnal rhythms.

The aim of the current study was to assess considerations for researchers wishing to utilize salivary cortisol obtained in naturalistic settings without face-to-face interaction with their participants. Recent technologies in saliva collection have made cortisol an increasingly popular hormone of study. Cortisol has been evidenced to have implications in cardiovascular disease (Loft, et al., 2007), diabetes (Korenblum, et al., 2005), and autoimmune responses (Neidhart, 1996), among many other physical health outcomes. While it is not the only biomarker that may be measured to investigate health consequences, much can be learned from it. Despite the four flags discussed in the paper, there is strong evidence that participants can comply with protocols including saliva collection on multiple occasions across multiple days and to do so reliably. In addition, the current study presents evidence that the flags discussed can be taken into consideration in ways that ultimately reduce methodological error and enhance study outcomes.

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Wust, S., Wolf, J., Hellhammer, D.H., Federenko, I., Schommer, N., Kirschbaum, C. (2000) The cortisol awakening response – normal values and confounds. *Noise and Health, 7, 77-85*.

Figure 2. Parameters of cortisol and the depiction of the diurnal rhythm.

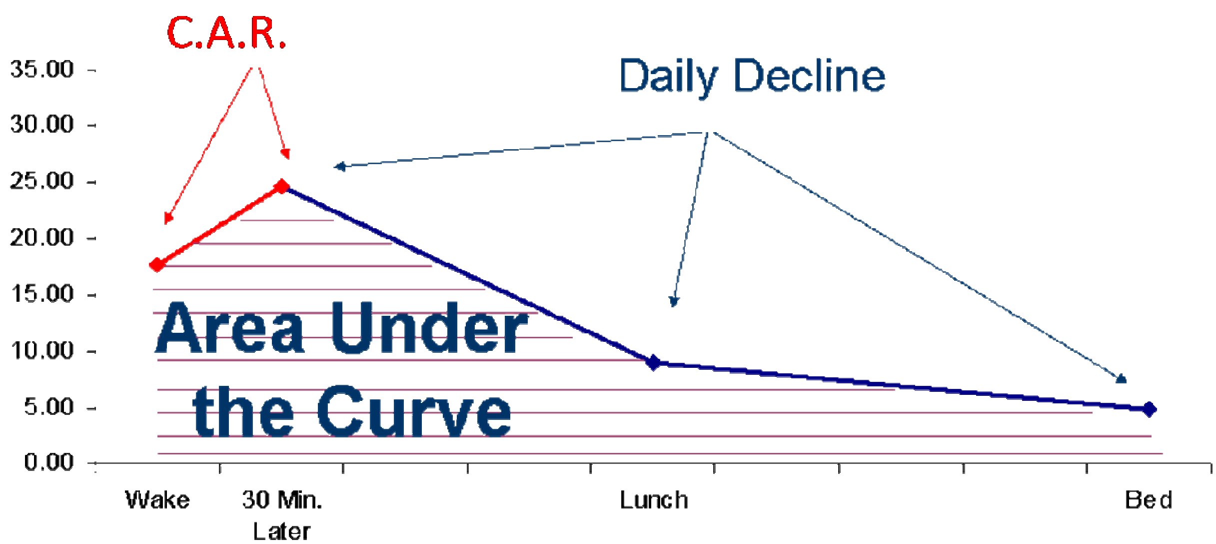

Figure 3. Flag 1, “Awake less than 12 hours or more than 20 hours” and the potential effect on the diurnal rhythm.

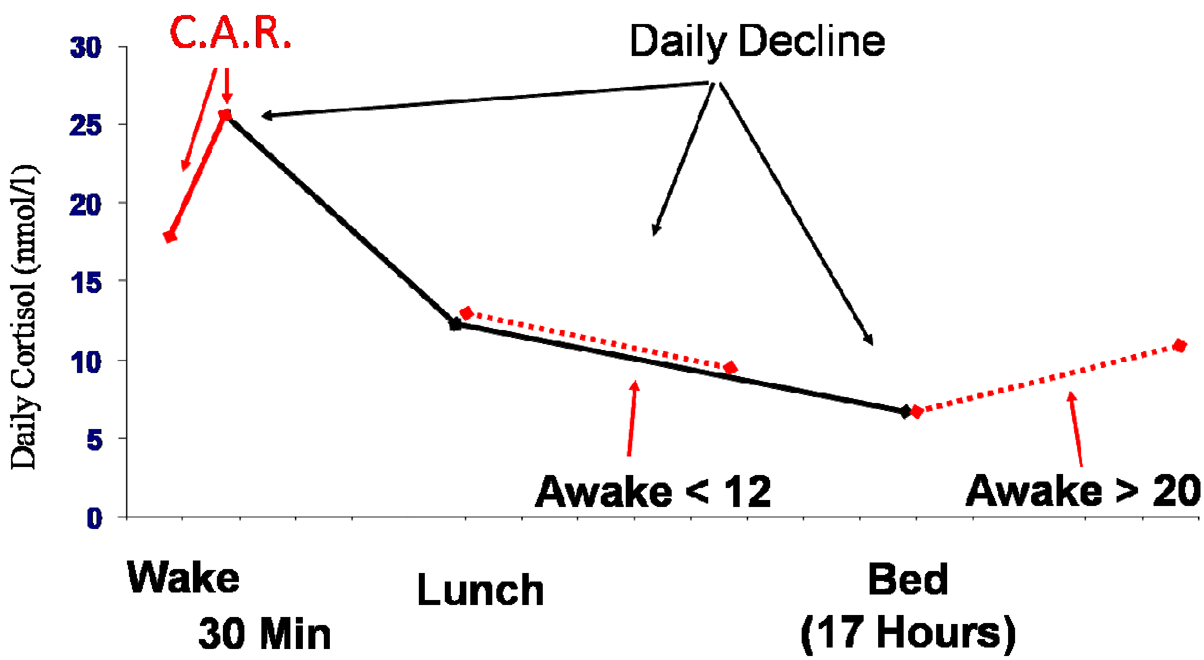

Figure 4. Cortisol flag 2: Days when individuals wake up after 12:00 pm.

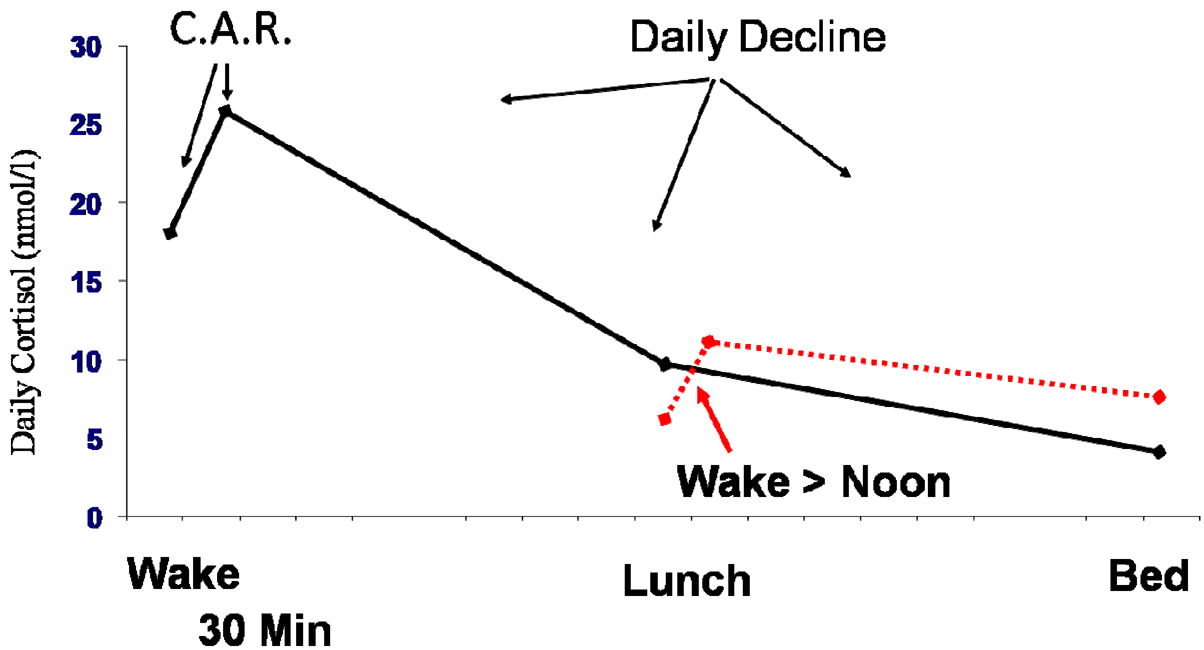

Figure 5. Flag 3: Higher lunch time cortisol value.

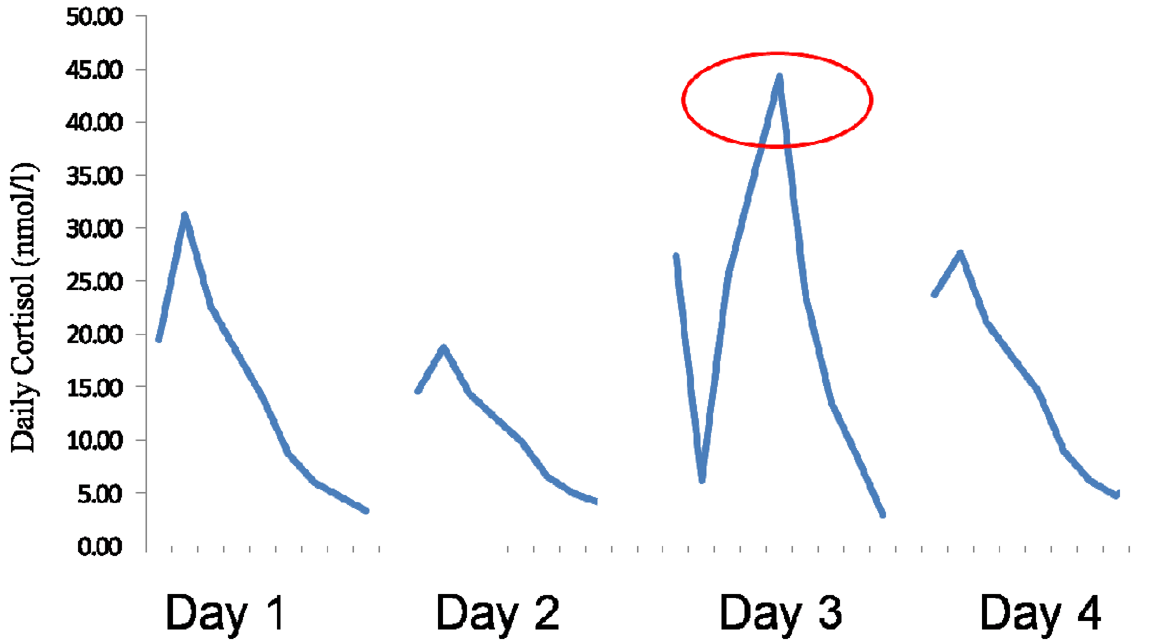

Figure 6. Flag 4: Time 2 Cortisol Provided at Incorrect Time.

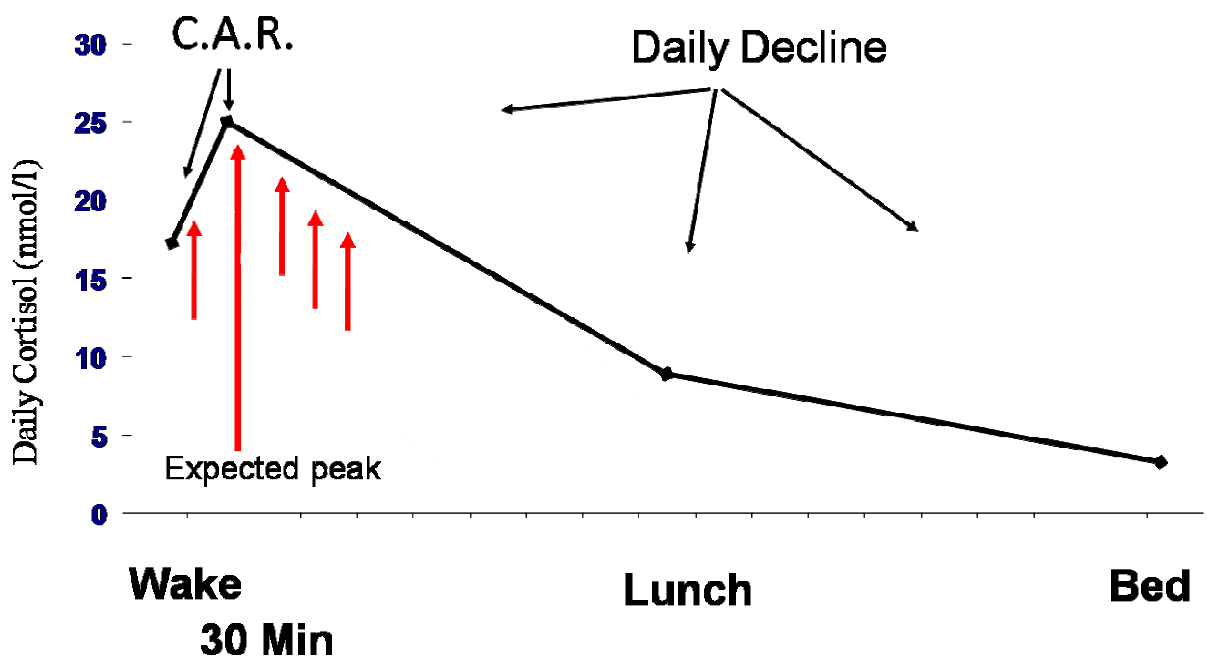

Table 7. Three-level dataset for hypothetical participant (99991).

NSDEID	day	Occasion	Cortisol	LogCort	Time	Piece1	Piece2
99991	2	1	8.58	2.15	3.75	0	0
99991	2	2	37.71	3.63	4.25	0.5	0
99991	2	3	11.69	2.46	11.5	0.5	7.25
99991	2	4	6.18	1.82	20.5	0.5	16.25
99991	3	1	30.57	3.42	3.75	0	0
99991	3	2	31.14	3.44	4.25	0.5	0
99991	3	3	5.85	1.77	11.5	0.5	7.25
99991	3	4	4.83	1.58	20.5	0.5	16.25
99991	4	1	22.98	3.13	4	0	0
99991	4	2	37.27	3.62	4.5	0.5	0
99991	4	3	17.94	2.89	11	0.5	6.5
99991	4	4	7.25	1.98	21	0.5	16.5
99991	5	1	26.04	3.26	4.5	0	0
99991	5	2	29.44	3.38	5	0.5	0
99991	5	4	4.19	1.43	21	0.5	16

Table 8. Summary of Cortisol Flags

Cortisol Flag	# of Days	% of Days	# of People	Concern	Recommendation
Flag 1					
Awake < 12	73	1.61%	52	Potential bias to daily decline	Do not include final occasion of cortisol,
Awake > 20	36	0.79%	29	daily decline.	thus dropping the daily decline parameter.
Flag 2				Potential bias for both CAR and	Do not include cortisol parameters for
Post-Noon	34	0.75%	16	daily decline parameters.	entire day of collection.
Flag 3					Do not include this occasion in analyses,
High Lunch	63	1.39%	53	Indication of non-compliance.	thus dropping the daily decline parameter.
Flag 4					
< 15 minutes	53	1.17%	37	Potential bias for both CAR and	Do not include cortisol parameters for
> 60 minutes	361	7.95%	210	daily decline parameters.	entire day of collection.
Cort Flag 1	552	12.15%	336		
Cort Flag 2	179	3.94%	127		

Table 9. Summary of Diurnal Parameters of Cortisol Based on 4 Cortisol Flags.

			Cortisol Awakening Response			Daily Decline			Area Under the Curve		
Days (N)	Intercept	SE	Estimate	SE	ICC	Estimate	SE	ICC	Estimate	SE	ICC
All Days (4521)	2.84	0.01	0.297	0.02	57.23%	-0.116	0.00	42.13%	88.49	0.46	58.17%
Flag1 (107)	2.67	0.07	0.399	0.22	69.79%	-0.074	0.01	29.11%	95.20	2.91	66.35%
Flag2 (33)	2.42	0.19	0.334	0.28	30.61%	-0.029	0.03	36.21%	104.36	8.64	77.69%
Flag3 (63)	2.65	0.08	0.718	0.07	2.20%	-0.044	0.01	32.59%	106.97	2.56	53.87%
Flag4 (387)	2.72	0.04	0.181	0.07	- *	-0.115	0.01	71.26%	90.42	1.21	49.23%
Cortflag=1 (552)	2.67	0.03	0.279	0.06	63.86%	-0.093	0.00	45.49%	93.50	1.13	52.67%
Cortflag=0 (3970)	2.87	0.01	0.300	0.02	56.09%	-0.119	0.00	30.88%	87.96	0.46	58.89%

Note: Cortflag = 1 are days when there is at least one cortisol flag. Cortflag = 0 represents days when there are no flags.

* CAR cannot be estimated on days when the second assessment is dropped.

Table 10. Comparison of Awakening Cortisol with Wust et al. (2000).

Study	N Persons	N Days	Wake Mean	Wake SD	30 Min Mean	30 Min SD
Wust et al. (2000)	509	2	15.12	6.3	22.95	9.1
NSDE (Initial Assays)	1,143	4	16.07	9.1	22.03	11.4

Table 11. Comparison of NSDE to Wust et al. (2000) on Average Daily Decline Slope.

Study	N Persons	Samples per Day	Average Slope	SD Slope
Kirschbaum-1	66	25 X 1 day	-.11	.04
Kirschbaum-2	20	49 X 2 days	-.11	.04
Cohen	176	9 X 2 days	-.10	.04
Smyth	39	3 X 24 days	-.12	.06
NSDE (Initial Assays)	1,143	3 X 4 days	-.12	.17

Table 12. Comparison of NSDE to Wust et al. (2000) on Top and Bottom Quintiles of Daily Decline Slope.

Study	Bottom 20% Slope	n Persons	Top 20% Slope	n Persons
Kirschbaum-1	-.05	13	-.17	13
Kirschbaum-2	-.05	4	-.17	4
Cohen	-.01	35	-.17	36
Smyth	-.01	8	-.19	8
NSDE (Initial Assays)	-.07	228	-.16	228

CHAPTER IV

AGE DIFFERENCES IN THE PREDICTIVE EFFECT OF EVENT-SPECIFIC CONTROL ON THE DIURNAL RHYTHM OF SALIVARY CORTISOL

Introduction

There is great variability in individuals' responses to stressful events. Many characteristics of the stressor itself contribute to the consequences of a stressful event. One important factor is the amount of control the individual experiencing the stressor perceives to have over the event (Neupert, Almeida, & Charles, 2007; Eizenman, Nesselroade, Featherman, & Rowe, 1997). The goal of the current paper is to show how perceptions of control over a stressful event affect physiological reactivity to the stressor, specifically by examining salivary cortisol. Cortisol is a hormone regulated by the HPA-axis and is commonly referred to as the "stress hormone" because of heightened secretion in the physiological response to stressful events (Dickerson & Kemeny 2004; Nicolson, Storms, Ponds, & Sulon, 1997).

Many studies have documented the role of personal control in the stress process, showing that unexpected events are more stressful than those that are scheduled (Thoits, 1983). But control is more than just predictability of an event. According to Wallston, perceived control is defined as the *belief* that one can determine internal states and behavior, influence the environment, and/or bring about desired outcomes (Wallston, Wallston, Smith, & Dobbins, 1987). Reich and Zautra (1984) found that individuals forced into involuntary retirement reported a decline in positive affect and life satisfaction. In comparison, only one third of individuals retiring voluntarily reported dissatisfaction. These results remained significant even after controlling for physical health symptoms. Additionally, both relocation and institutionalization only lead to negative psychological outcomes when older individuals perceived these moves as involuntary or out of their control (Reich & Zautra, 1984). In a study examining the effects of a noise-induced stressor on physiological responses, individuals with a high internal locus of control who perceived they were in control of the noise showed a lower cortisol response than those who did not perceive to be in control (Bollini et al., 2004).

Perceptions of control also have important implications in physiological stress reactivity, as there is some evidence that stressors involving perceived loss of control have highest cortisol responses. An association between personal control and cortisol was reported in 767 middle-aged adults (Brandstedter, et. al, 1991) such that lower feelings of control were associated with higher cortisol levels. Similarly, self-esteem and internal locus of control have been associated with hippocampus volume and better regulation of cortisol in healthy individuals (Pruessner, et. al, 2005); however, not all studies have found differences in the effects of perceived control over a stressful event on cortisol. Smyth and colleagues (1998) reported no association between subjective perceptions of uncontrollability and cortisol reactivity. To date, there has been little empirical examination of the relationship of uncontrollability and cortisol responses (Dickerson & Kemeny, 2004).

The Current Study

The current study investigates the effect of event-specific control (ESC) on the diurnal rhythm of salivary cortisol. Stressor reactivity refers to the level of response likely to be experienced by an individual following a stressful event. While there are potentially many characteristics of a stressful event that affect stressor reactivity, the amount of control an individual perceives to have over the experience may be a powerful predictor of physiological response. For example, an individual perceiving high control over an argument with a co-worker might have less reactivity than another stressful event in which she perceives less control. Control, in this sense, is related specifically to the event, in contrast with global or trait measures of control, which measure overall perceptions of how the individual affects his or her environment. This paper examines the predictive effect of ESC on the cortisol awakening response, daily decline, and area under the curve of salivary cortisol. In addition, the paper examines the role of age and trait control as potential moderators of this relationship.

Stress and Cortisol

Perhaps the most widely cited literature regarding intraindividual differences in HPA-axis reactivity relates to the effect of psychological and physiological stressors on cortisol. Stressful experiences have consistently been implicated in affecting cortisol (Kudielka et al, 2004; Smyth et al, 1998; Dickerson & Kemeny, 2004; Burke et al, 2005; Otte et al, 2005). In addition to just the occurrence of stressors, subjective reports of stressor severity are also positively correlated with cortisol secretion (Smyth, et. al, 1998). There is also some evidence for age by stressor interactions in cortisol, such that older individuals show higher cortisol response following a challenging task compared to their younger counterparts (Otte, et. al, 2005).

Dickerson and Kemeny's (2004) review article on the effects of acute laboratory stressors on cortisol response has gained much attention. The article is a meta-analysis, reviewing 208 laboratory studies inducing stressors in both humans and animals and measuring cortisol outcomes. The authors argue that "uncontrollability" is one characteristic related to the stressor that has the potential to affect cortisol response. In addition, in humans, stressors that directly threaten self-preservation, or challenge the individual's self-identity seem to have the highest implications on cortisol response (Dickerson & Kemeny, 2004).

One common stress-inducing situation is a public speaking task, which many studies have found to result in cortisol increases. In one study comparing cortisol responses in 106 smoking and non-smoking individuals, both groups had significant increases in cortisol after public speaking (Buchmann et al., 2008). Another study compared patients with anxiety disorders to controls and also found increased cortisol levels following a public speaking task (Garcia-Leal, et al., 2005). A third study investigated the role of extraversion and introversion in 45 college students performing a public speaking task. Interestingly, results showed a cortisol increase in the majority of students (n=35) but a decline in cortisol levels in the remaining students (de la Banda et al., 2004).

All of these studies rely on pre- and post-stressor measurements of saliva samples; however, collecting samples over the course of an entire day provides better evidence for how stress may affect the diurnal rhythm of cortisol. Cortisol daily decline seems to be particularly susceptible to change following a stressful event. After experiencing a stressful event, individuals should show increased cortisol levels for a brief period of time. Laboratory studies involving stress-inducing tasks, on average, have shown cortisol levels returning to baseline within one hour following the stressor. Yet even in acute stressors, rises in the slope of the daily decline can be detected (Dickerson & Kemeny, 2004). Overactivation, or a daily decline slope closer to zero, is hypothesized to represent an accumulative physiologic reaction to a lifetime of stressful events (Kudielka, et. al, 2004).

Many of the studies examining stress exposure and cortisol response have relied on laboratory manufactured stressors. The majority of these studies have been conducted on young adults; however, there is evidence for age differences in cortisol levels and stressor reactivity. Before discussing these studies, it may be helpful to provide a background in age differences in perceived control and exposure to daily stressors.

Age and Perceived Control

Research focusing on perceived control has often looked to age as a variable to help explain individual differences. In a national sample of older adults, participants were asked to respond to the statement, “What happens in life is beyond my control.” Results showed that younger adults were more likely to disagree with this statement compared to older adults (80% vs. 62% respectively; Lachman & Firth, 1994). As one of the leaders in developmental theories of control, Lachman has consistently advocated for domain-specific measurements of perceived control, rather than relying solely on global measures of control to explain age differences (Lachman, 1986; Lachman & Weaver 1998; Lachman, 2006). In a review of age-related perceptions of control in several domains, Lachman found evidence for older adults to be more internally focused in their perceptions of control compared to their younger counterparts (Lachman, 1986).

Krause (2007) has also found evidence for age differences in domain-specific perceptions of control. A longitudinal study measuring control in older adults across 11 years found that in domains that are most highly valued by individuals, there is a decline in perceptions of control with age. This result was also confirmed with cross-sectional analyses, showing that younger adults reported higher perceptions of control than older adults in their most highly valued domain. In addition to age differences in domain specific perceptions of control, there is also evidence that differences in control may be associated with physiological outcomes.

Chronological Age and Daily Stressor Exposure

Throughout adulthood, individuals are faced with many challenging situations and stressful events. Chronological age is an important indicator and predictor of stressor exposure and many studies have described age differences in exposure to stressful events. On average, adults typically report experiencing at least one stressful event on 4 out of every 10 days (Almeida, 2005). As individuals age, however, their experiences of daily stressful events change. Adults in their late twenties and early thirties report having stressful events more often than adults in other age groups and subjectively report higher intensity of these events (Almeida, 2005). When stressful events do occur for older adults, however, objective ratings of severity are higher than those experienced by younger adults. (Almeida & Horn, 2004; Chiriboga, 1997).

Midlife adults tend to report a higher proportion of stressors posing financial risk and stressors involving children than do young adults or the elderly. In addition, mid-lifers also report fewer stressors during which they feel like they have little or no control (Almeida & Horn, 2004). Compared to older individuals, both young and middle aged individuals experience greater daily frequency of stressors as well as a greater number of days during which they experience multiple stressors. As with younger individuals, midlife adults also perceive of their stressors as more severe than older adults (Almeida & Horn, 2004).

Older individuals, aged 60-74 years, typically report experiencing fewer daily stressors than their younger counterparts. When reporting daily stressful events, older adults tend to have stressful experiences primarily related to limitation in activities and health-related events (Folkman & Lazarus, 1988). In terms of stressor severity, older individuals seem to rate stressors related to family and friends as most stressful (Pearlin & Skaff, 1998; Landreville & Vezina, 1992).

Salivary Cortisol – Parameters of the Diurnal Rhythm

Recall that cortisol is regulated by the hypothalamic-pituitary-adrenal (HPA) axis. The three parameters of salivary cortisol's diurnal rhythm have distinct implications on HPA-axis functioning and health. The cortisol awakening response (CAR) represents an individual's ability to prepare for the day ahead. Blunted awakening responses have been associated with depression and anxiety (Shea, et al., 2007; Greaves-Lord et al., 2007). The daily decline of cortisol represents an individual's physiological ability to "shut-down" throughout the day before sleep. This parameter might be most associated with chronic stress (Wingenfeld, et al., 2009). In addition, patients with depression and anxiety disorders and chronic health conditions have all been shown to have low diurnal slopes (Taylor, Glover, Marks, & Krammerer, 2009; Steptoe et al., 2000; Ranjit, Young, Raghunathan, & Kaplan, 2005). Finally, area under the curve (AUC) represents the total secretion of cortisol within an individual across a day. While there have been articles describing how to measure AUC (Pruessner, et al., 2000; Hrushka, Kohrt, & Worthman, 2005), there is no consensus on what the parameter represents as a function of health above and beyond either the awakening response or the daily decline of cortisol. For a more detailed description of each of these parameters, as well as how they are calculated, please refer to the second paper in this dissertation.

Age and Cortisol

In addition to predicting stressor exposure, age is also an influential factor in determining stressor reactivity. This is particularly true when measuring physiological responses like cortisol secretion. Chronological age has been the most widely studied between-person difference in cortisol research. Results across studies have consistently shown that older adults have higher baseline cortisol levels when compared to their younger counterparts (Van Cauter et al, 1996; Deuschle et al, 1997; Ice et al, 2004; Seeman et al, 2001; Kudielka et al, 2004). Several studies have shown average levels of cortisol are higher for older individuals (Deushcle et al, 1997; Seeman et al, 2001; Kudielka et al, 2004), with some studies showing levels increased by as much as 75% (Van Cauter et al, 1996). There is also evidence of an age by gender interaction such that older females have higher mean levels of both plasma cortisol (Kudielka et al 2004, Van Cauter et al, 1996) and salivary cortisol (Kudielka et al, 2004).

While there is agreement that older participants exhibit higher cortisol levels, most often these increased values are well within the normal range for healthy individuals (Deuschle et al, 1997). Although not clinically significant in terms of health outcomes, this finding is an intriguing one. One explanation is the "wear and tear" theory in which individuals are thought to accumulate a lifetime of stressful events. Due to overuse or because of natural biological responses, the HPA axis could be more susceptible to heightened reactivity following stressful events, thus not returning to its original baseline state (McEwen, 1998). These biological processes implicated in aging contribute to heightened cortisol reactivity – both physically and psychologically. This "kindling" hypothesis has been applied to age, neuroticism, and negative affect (Mroczek & Almeida, 2004). As adults age, the biological imperative determines that constant adaptation lowers the threshold to a given stimulus due to neuroplasticity. In addition to age differences in cortisol levels, there is also evidence for age differences in perceived control.

Perceived Control and Cortisol Reactivity

Physiological reactions to changes in perceived control have been studied in both humans and animals. There is evidence across a variety of studies that lack of control is associated with negative physiological outcomes including rises in cortisol (corticosteroid in animals), and various catecholamine, neurohormonal, and immune changes (Rodin, 1986; Wallston, Wallston, Smith, & Dobbins, 1987). "Countless experimental manipulations (e.g.,uncontrollable or inescapable shock, noise) in animal studies seem to lead to an unhealthy state. Tumor growth, gastric ulceration, and weight loss have been used as outcome measures" (Wallston, et al., 1987, p. 17).

Experimental studies investigating alterations in control have been conducted in animals due to the ease with which control over stressful stimuli can be manipulated. For example, Davis and colleagues (Davis, Greene, Herrmann, & Levine, 1977) conducted a study using Long-Evans hooded rats in which control was manipulated by exposing rats to extreme noise and/or shock treatment. Results showed increased corticosterone responses in all rats, but higher levels were shown in rats that were able to escape, and thus control, the stressful situation (Davis, et al., 1977). These same results were replicated in C57BL/KA mice, showing increased corticosterone responses following stressful stimuli with lack of control (Hennessey & Levine, 1978).

One study examining the effect of subjective control[2] on cortisol in humans was conducted on 48 college students who were exposed to loud, aversive noises via headphones (Bollini, Walker, Hamann, & Kestler, 2004). Participants in the perceived control condition were able to manipulate the intensity of the loud noises. Saliva samples were provided every 6 minutes throughout the study with a total of 12 samples provided. Results showed no main effects for control on cortisol levels; however, there was an interaction with trait levels of control whereby individuals with a higher internal locus of control in the perceived control condition showed elevated cortisol levels, whereas those with a low internal locus of control had lower cortisol levels. Individuals in the no control condition showed no cortisol response, regardless of locus of control (Bollini et al., 2004).

The previous study highlights the importance of including trait levels of control in concordance with event-specific perceptions of control. As discussed in the second chapter of this dissertation, trait levels of control, such as locus of control, represent general perceptions of control across domains. The present study examines the effect of event-specific control on the diurnal rhythm of salivary cortisol. In addition to event-specific control, the moderating effects

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[2] It is important to note that there is a long literature on perceived v. “actual” control. The current research investigates perceived control. For a review of this literature, refer to Frankenhauser, (1989). A biopsychosocial approach to work life stress. *International Journal of Health Services*. 19, 747–758.

of age and trait levels of control will be investigated. With this in mind, the paper will address the following research questions.

Research Questions

1. Does event-specific control predict parameters of the diurnal rhythm of cortisol for various types of stressful events?
2. After examining different types of stressors, what is the predictive effect of event-specific control over all types of stressors?
3. Does age moderate the effect of control on these parameters?
4. How do trait measures of control moderate the effects of event-specific control on cortisol parameters?

Method

Participants

Participants for the present study come from the initial set of respondents participating in the second wave of the National Study of Daily Experiences (NSDE, N = 1,265). Participants for the NSDE come from a subsample of the National Survey of Midlife in the United States (MIDUS), a nationally representative telephone-mail survey of 4,963 people aged 35-84, conducted in 2003-2004, under the auspices of the MacArthur Foundation Research Network of Successful Midlife Development. Participants in the NSDE completed short telephone interviews across eight consecutive evenings about their daily experiences. The current response rate for the study is 76% with a retention rate of 96%. On average participants provided a mean of 7.5 interviews per 8 days (summing to a total of 10,120 interview days). Table 13 shows demographic characteristics of both the MIDUS and NSDE samples. For the current analyses, only those participants who agreed to provide saliva samples were included (N = 1,143; 90 %).

Insert Table 13 about here

Recruitment and Interview Procedure

Approximately one week before telephone contact, participants received a package containing a recruitment letter and a summary of previous findings, a check for $25, as well as a "Home Saliva Collection Kit". The kit contained instructions for saliva collection, a "Home Collection Sheet" for documenting the times samples were collected, 16 salivettes, a self-addressed UPS bio-hazard package with pick up instructions, and finally a stress ball as a token of appreciation for participating in the study.

Approximately one week after recruitment mailing, an initial call was made to participants requesting their participation in the study. The daily telephone interview consisted of time use (including social support), physical symptoms, alcohol and tobacco use, negative and positive affect, productivity, in-depth assessment of stressors, positive events, medications, and a weekly review (on day 8 only).

Daily Stressful Events

Daily stressors were assessed through the semi-structured Daily Inventory of Stressful Events (DISE, Almeida et al., 2002). The inventory consisted of a series of seven stem questions asking whether different types of daily stressors (i.e., arguments, potential arguments, work stressors, home stressors, network stressors, discrimination stressors, and other stressors) had occurred in the past 24 hours. For example, participants were asked, "In the past 24 hours, have you experienced anything at work that most people would consider stressful". Individuals who responded "yes" to a stem question received a value of one for that stressor. The present study utilized three stressor domain variables: interpersonal stressors (arguments, tensions, or stressors involving other people; 50% of all stressors reported), overloads (demands that tax the individual or stressors not involving other people; 38% of all stressors reported), and network stressors (whether anything happened to a close friend or family member that turned out to be stressful for the respondent; 12% of all stressors reported). Interpersonal, work, home, and network stressors represent 87% of all stressors reported. The remaining 13% of stressors included experiences of discrimination (1.2%) and those not falling under any specific category (11.8%). In terms of the overall daily diaries, interpersonal stressors occurred on 21% of days, overload stressors occurred on 16% of days, and network stressors occurred on 5% of days. Table 14 summarizes the frequency of these events by day and for individuals and also provides descriptive statistics for the variables of interest for the present study.

Insert Table 14 about here

Personal Mastery and Perceived Constraint

Control belief variables were assessed in the MIDUS survey. These measures were developed from Pearlin and Schooler's (1978) mastery scale with five additional items specifically designed for the MIDUS (Lachman & Weaver, 1998). Respondents rated on a 7-point Likert scale (1 = strongly agree, 7 = strongly disagree) how strongly they agreed with each statement. For the mastery scale, participants responded to the following statements: a) I can do just about anything I really set my mind to; b) When I really want to do something, I usually find a way to succeed at it; c) Whether or not I am able to get what I want is in my own hands; and d) What happens to me in the future depends mostly on me. Responses were coded so higher scores indicated greater personal mastery for each person (Chronbach's α = .70). For the constraints scale, participants responded to the following questions: a) There is really no way I can solve all the problems I have; b) There is little I can to do change the important things in my life; c) I often feel helpless in dealing with the problems in life; d) Other people determine most of what I can and cannot do; e) What happens in my life is often beyond my control; f) There are many things that interfere with what I want to do; g) I have little control over the things that happen to me; and h) I sometimes feel I am being pushed around in my life. Responses were coded so higher scores indicated greater perceived constraints for each person (Chronbach's α = .86). These measures have been used successfully as valid indicators of personal mastery and perceived constraints in several studies (e.g., Lachman & Firth, 2004; Lachman & Weaver, 1998).

Event Specific Perceived Control (ESC)

Perceived control was measured in the context of a daily stressful event. An affirmative response to a stressor stem question resulted in obtaining detailed information about the event. Control was measured using the question, "During this situation, how much control were you feeling?" Responses to this question were measured by a 4 point Likert scale including, "none at all", "a little", "some", or "a lot" where 1 = "not at all" and 4 = "a lot".

Saliva Collection

In addition to the daily telephone interview, participants were instructed to provide saliva samples on days 2 through 5 of the study, at 4 time points throughout the day: immediately upon awakening, 30 minutes after awakening, before lunch, and before bed, for a total of 16 samples

(4 times on 4 days). The directions instructed participants to provide saliva samples at least 1 hour before eating, drinking, consuming caffeine, or brushing their teeth. Upon completion of the collection, participants were instructed to arrange for the kit to be picked up by UPS.

Saliva Statistics

Of the 1,265 respondents, 1,143 provided saliva samples (90%)[3]. Of the 18,288 possible samples (1,143 x 16 samples), there were 546 missed samples or samples with insufficient volume to detect cortisol (~ 3%). A small portion of samples yielded cortisol data considered out of range (i.e. above 120 nmol/l; 305; < 1%). These data resulted in final cortisol analyses based on 96 % usable samples (N = 17,465 samples).

Limiting Cortisol Sample – Four cortisol flags were addressed in order to obtain an accurate depiction of the diurnal pattern of cortisol. If any of the following flags occurred, the individual's cortisol data was removed from analyses for the day.

Flag 1: Awake Less than 12 or More than 20 hours (N = 109 or 2.4% of days)

The first cortisol flag describes days during which individuals are awake for an atypical amount of time. This includes days during which individuals are awake for less than 12 hours or more than 20 hours.

Flag 2: Wake Past Noon (N = 34 or 0.75% of days)

Another potential problem with the sleep patterns of an individual occurs on days during which individuals report waking up after 12:00 pm. This becomes a problem because of an asynchrony with the natural light-dark cycles. A day where an individual works a night shift would be an example of this occurrence.

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[3] The final analyses for paper 3 include only those individuals who provided saliva samples. Therefore, Ns will be different than those reported in paper 1, when salivary cortisol was not taken into account.

Flag 3: High Lunch Time Cortisol (N=63 or 1.39% of days)

The third cortisol flag occurs on days during which an individual's lunch time cortisol collection is their highest point in their day. The present study operationalizes "higher" lunch time cortisol as being 10 or more nmol/l higher than the second collection point (which should be an individual's highest point) of the day.

Flag 4: Post-wake (Time 2) Assessment Provided at Wrong Time (N = 414 or 9.12% of days)

The final cortisol flag occurs on days during which a participant fails to provide the second sample when instructed. Recall, an individual's cortisol rises to its peak of the day between 30 and 45 minutes after waking up. This flag represents days when individuals reported providing their sample either too soon (less than 15 minutes) or too long (more than 60 minutes) after their initial sample.

Multilevel Modeling

Multilevel modeling was used to estimate parameters of daily cortisol. In these models, three levels are utilized: occasions, days and individuals. Occasions are nested within days and days nested within individuals. The following equations describe this three level model

$$\text{L1: } Cort_{odi} = \beta_{0di} + \beta_{1di}\, MR_{1odi} + \beta_{2di}\, DD_{2odi} + r_{odi}$$

where cortisol on a given occasion (o), on a given day (d), for a given individual (i) is a function of an individual's baseline measure (or intercept, β_{0di}) , plus that individuals slope for their morning rise for that occasion on that day ($\beta_{1di}\, MR_{1odi}$), plus their slope for daily decline at that occasion on that day ($\beta_{2di}\, DD_{2odi}$), plus random fluctuation around their level (error). At level 2 the outcomes are the daily parameters of circadian rhythm of cortisol:

$$\text{L2: } \beta_{0di} = \delta_{00i} + U_{0di}$$

$$\text{L2: } \beta_{1di} = \delta_{10i} + U_{1di}$$

$$L2: \beta_{2di} = \delta_{20i} + U_{2di}$$

where the intercepts and slopes on each day are modeled as a function of the mean for the each individual plus an individual's deviation from their own mean across the four days. At level 3 the outcomes represent the mean of the circadian parameters across the four days for each individual

$$L3: \quad \delta 00i = \gamma 000 + V00i$$

$$L3: \quad \delta 10i = \gamma 100 + V10i$$

$$L3: \quad \delta 20i = \gamma 200 + V20i$$

Within person slopes for daily cortisol levels were estimated using a piece-wise (spline) model such that piece one represented the morning rise and piece two represented the daily decline. Step one was to "stack" the data in a person-day file such that each row represents one occasion on one day for one individual.

All multilevel models were conducted using the PROC MIXED command in SAS (v. 9.0). Intraclass correlations (ICC) were calculated by running a model with perceived control as the dependent variable and no predictors (empty model).

The final models for the current analyses utilized a mean-centered approach for personal mastery (PM) and perceived constraints (PC), both trait measures of control. In addition, for all event-specific control analyses, a lagged variable was set up such that today's ESC predicting tomorrow's cortisol awakening response. This was done because one would only expect a stressful event to impact CAR if the event occurred within 30 minutes of awakening.

Results

The present study investigated the effects of event-specific control (ESC) over stressors on parameters of salivary cortisol. All analyses control for the number of stressful events experienced by the individual on a given day and across the eight days of the study. The first research question examined the effect of ESC on cortisol levels following the experience of specific stressful events. Table 15 provides a summary of these results. Event-specific control over overload stressors approached significance for cortisol awakening response (*B* = 0.05, SE = 0.05; $p < .10$). ESC did not significantly predict any of the other parameters of the diurnal rhythm of cortisol for different stressful events.

Insert Table 15 about here

The second research question for the present study examined the predictive effect of ESC's effects on cortisol levels for all stressors. The first model, presented in Table 16, introduced ESC on stressors for parameters of salivary cortisol. ESC did not significantly predict AUC (*B* = 0.35, SE = 2.01; *p* = n.s.) or CAR (*B* = -0.14, SE = 0.15; *p* = n.s.). ESC significantly predicted salivary daily decline (*B* = -0.02, SE = 0.01; $p < .05$). In order to address research questions 3 and 4, Model 2 added age and trait control.

Insert Table 16 about here

Age significantly predicted both AUC (*B* = 0.36, SE = 0.08; $p < .01$) and daily decline (*B* = 0.01, SE = 0.01; $p < .05$) but not CAR (*B* = 0.00, SE = 0.00 *p* = n.s.). Older individuals had significantly higher AUC and significantly lower daily decline slopes. Recall, trait levels of control were mean centered. Perceived constraints (*B* = 0.01, SE = 0.00; $p < .05$) and personal mastery (*B* = -0.02, SE = 0.00; $p < .01$) were also significant predictors of daily decline but not AUC or CAR. Individuals with above average PC had significantly less steep daily decline slopes and individuals with above average PM had significantly steeper daily decline slopes. The final model introduced interactions of age, perceived constraints, and personal mastery. One significant interaction was found between age and ESC on daily decline. The interaction is presented in Figure 7. Younger individuals with low ESC had significantly higher daily decline slopes of salivary cortisol compared to those with high ESC. Daily decline slopes did not change for older adults regardless of ESC.

Insert Figure 7 about here

Discussion

The overarching goal of the present study was to examine the effect of event-specific control on the diurnal rhythm of salivary cortisol. Cortisol has been growing in popularity among researchers interested in the stress process. Control over stressful events and the implications on physiological outcomes has been one particular area within the stress process that has also been gaining attention. The first aim of this study was to investigate the role of event-specific control over various types of stressors on salivary cortisol outcomes. There were no significant effects on cortisol levels related to ESC over specific stressful events; however, looking at stressful events as a whole, ESC was a significant predictor of daily decline of salivary cortisol. In addition, ESC approached significance for overload stressors in predicting cortisol awakening response. This suggests that more power could be needed in order to detect differences in salivary cortisol by specific stressor events.

The most interesting result of the present study is event-specific control having predicting the daily decline of salivary cortisol. The daily decline represents the HPA-axis shutting down for the day as individuals go to bed and reenergize for the next day. Stressful events are associated with less steep slopes of daily decline (Kudielka et al, 2004; Smyth et al, 1998). The finding that stressors over which individuals perceive less control have an even flatter slope, validates examining control as a vital aspect of the stress process.

Previous studies have shown that loss of control over stressful events affects physiological functioning (Rodin, 1986; Wallston, Wallston, Smith, & Dobbins, 1987). The current study replicates these findings for the daily decline of salivary cortisol but not for the cortisol awakening response. Stressful events typically do not occur within 30 minutes of awakening. For this reason, the current study utilized "lagged" methodology in which today's ESC predicted tomorrow's CAR. Even so, no significant results were found. One reason for this could be that the current study investigates daily stressful events, typically representing day-to-day hassles. While severe stressors were bound to occur throughout the study, the majority of these events did not fall into this category. It is possible that only the most severe stressful events have implications lasting long enough to affect physiological outcomes for an extended period of time. Previous research investigating cortisol in the stress process has shown that, following stressful events, individuals typically return to baseline measures within 30 minutes to an hour of the event (Dickerson & Kemeney, 2004). Even in light of these findings, the current study showed that on average, individuals who perceived less control over stressors had higher diurnal slopes of salivary cortisol.

Another aim of the present study was to examine the moderating effects of age and trait measures of control on the relationship between ESC and salivary cortisol outcomes. Both age and trait levels of control were associated with daily decline of cortisol, but not CAR. Age was a significant predictor of AUC, with older individuals having higher AUC. Most importantly, there was a significant interaction between age and ESC on daily decline of cortisol such that younger individuals with low ESC had less steep slopes in the daily decline of salivary cortisol. For older individuals, ESC did not have an effect on their daily decline.

There could be a few explanations for this result. Younger adults typically report higher subjective severity of stressful events (Almeida & Horn, 2004). Whether or not the stressor is objectively more severe may be less important than how an individual perceives the event. Older adults have more experience with dealing with day-to-day stressors and thus may be psychologically and physiologically more prepared to deal with such occurrences.

Another explanation could lie in theories of allostatic load. Allostatic load refers to the gradual wear and tear of an individual's HPA-axis functioning as a result of a lifetime of physiological taxation from responses to stressors (McEwen, 1998). Since older individuals, on average, have less steep declines in their diurnal cortisol, it may be the case that ESC has less of an effect on their physiological system. The current study investigated diurnal rhythms of salivary cortisol as the outcome; however, future studies could test this theory by examining other biomarkers of stress.

One of the limitations of the current study is relying solely on one biomarker as a proxy for physiological health. Cortisol is one of many potential physiological indicators related to the stress process. Extant studies have combined parameters of cortisol with physiological measures related to the immune system such as IL-6 (Starkweather, 2007) or cardiovascular functioning such as blood pressure (Brody, et al., 2002). Combining these types of biomarkers could open a window to broader implications on how daily stressors effect both short and long-term health.

The single-item measure of event-specific control is perhaps the most important limitation of the current study. One question, which asks how much control an individual perceived over a stressful event, may not completely capture the phenomenon of interest. Even given this limitation, the fact that this single-item measure significantly predicted daily decline of cortisol should prompt researchers to further develop measures of event-specific control for future investigation.

In order to test the effects of ESC on specific stressful events, future studies could benefit from investigating only those stressful events that are rated with the highest severity. Participants in the current study were asked to report any stressful event that occurred throughout their day. By limiting analyses to only those events rated as the most severe, one could potentially see larger effects of ESC on physiological outcomes. In addition, the timing of the stressor may play an important role on the diurnal rhythm of cortisol. Events occurring during the morning may have a different effect on the diurnal rhythm than those events occurring later in the afternoon or evening. It may be additionally beneficial to follow participants longitudinally to determine whether perceptions of control over stressful events change over time within adults and, if so, how this affects diurnal patterns of cortisol.

The current study provides novel insights into the role of event-specific control in the stress process. The fact that a psychological perception related to the stressful event can affect physiological outcomes provides further evidence of the complex nature of the mind-body connection as it relates to the stress process. The current state of the science would be improved by future research in this area involving investigation of the larger implications of event-specific control over stressful events and on long-term health.

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Table 13. Demographic Comparison of the MIDUS Sample and NSDE Sample.

Demographic Variable	Breakdown	Wave 1		Wave2	
		MIDUS%	NSDE%	MIDUS%	NSDE%
Age	Young Adults, 25-39	33.2	33.5	9.6	8.3
	Midlife Adults, 40-59	46.0	45.0	43.0	41.9
	Older Adults, 60+	20.8	21.5	47.4	49.8
Gender	Males	48.5	45.5	46.7	42.9
	Females	51.5	54.5	53.3	57.1
Education	12 Years of Less	39.2	37.7	33.4	32.4
	13 Years or More	60.8	62.3	66.6	67.6
Marital Status	Married	64.1	65.4	70.6	72.6
	All Others	35.9	34.6	29.4	27.4
Children in Household	Yes	39.0	37.8	30.6	28.1
	No	61.0	62.2	69.4	71.9
Race	Caucasian	84.1	86.3	85.9	88.3
	African American	10.8	9.7	9.1	8.2
	All other Races	5.1	4.0	5.0	3.5

Table 14. Descriptive statistics for variables including in analyses.

	% Days	% of People		
Interpersonal Stressors	21	71		
Overload Stressors	16	58		
Network Stressors	5	27		
	Mean	**SD**	**ICC**	**% W/in**
Event-Specific Control	1.44	1.18		
Age	57.28	12.43		
Personal Mastery	5.71	1.03		
Perceived Constraints	2.55	1.14		
Cortisol Awake Response	0.26	1.15	22.41%	77.59%
Cortisol Daily Decline	-0.11	0.07	32.76%	67.24%
Area Under the Curve	86.06	17.51	54.49%	45.51%

Table 15. Event-specific control over different stressors predicating parameters of salivary cortisol.

	Inter. Stressors	Overloads	Network Stressors
	B (SE)	B (SE)	B (SE)
Cortisol Awake Response	0.01 (0.04)	0.05^{t} (0.05)	0.03 (0.12)
Cortisol Daily Decline	0.00 (0.02)	0.00 (0.00)	0.00 (0.01)
Area Under the Curve	0.32 (0.67)	-0.88 (0.75)	2.01 (1.99)

$^{t} = p < .10$

** Analyses control for the number of stressful experiences an individual reported across the 8 days of the study.*

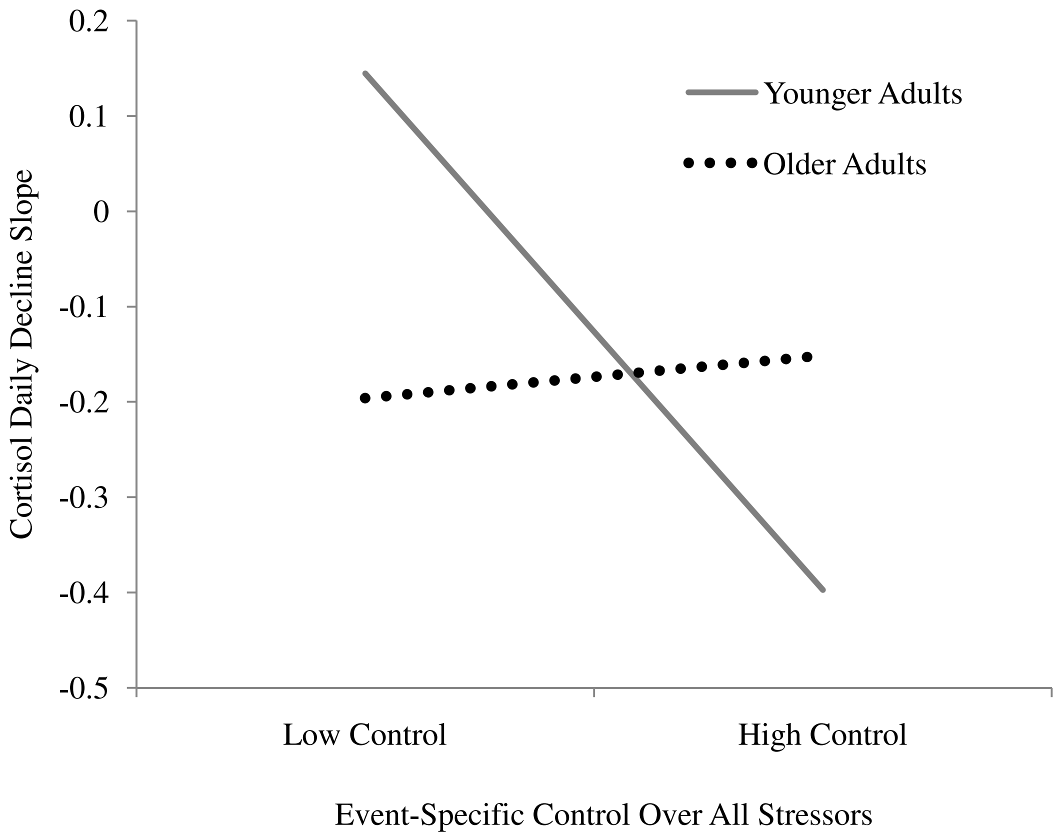
Table 16. Event-specific control over all stressors and moderators predicting salivary cortisol.

	AUC	CAR	Daily Decline
	β (SE)	*β* (SE)	*β* (SE)
Step 1			
Intercept	66.96*** (4.39)	0.07 (0.31)	-0.15*** (0.02)
ESC	0.35 (2.01)	-0.14 (0.15)	-0.02* (0.01)
Step 2			
Age	0.36*** (0.08)	0.00 (0.00)	0.01* (0.01)
Perceived Constraints (PC)	-0.15 (0.97)	0.01 (0.07)	0.01* (0.00)
Personal Mastery (PM)	0.89 (1.05)	0.01 (0.07)	-0.02*** (0.00)
Step 3			
Control x Age	-0.01 (0.04)	0.00 (0.00)	-0.01* (0.00)
Control x PC	0.46 (0.48)	-0.02 (0.03)	0.01 (0.00)
Control x PM	0.44 (0.52)	0.03 (0.04)	0.00 (0.00)

*** $p < 0.001$; ** $p < .01$; * $p <.05$

** Analyses control for the number of stressful experiences an individual reported across the 8 days of the study.*

Figure 7. Event-Specific Control by Age Interaction on Cortisol Daily Decline Slope.



CHAPTER V

CONCLUSION

The amount of control an individual perceives to have over a stressor greatly contributes to consequences following the event. Measuring perceived control in conjunction with the stress process is not a new phenomenon. For decades, researchers have known that global measures of control one perceives to have over their surroundings can greatly affect the individual. Moving forward, examining control at the event level may prove to be a fruitful path for control and stress research.

The three studies in this dissertation focused on event-specific perceptions of control (ESC), salivary cortisol, and the daily stress process. There were three main goals for the dissertation. Paper 1 addressed how perceived control can vary within individuals as well as across events. Results showed that event-to event variation was more than two times higher within individuals compared to between individuals. In other words, individuals were more likely to differ from themselves from event-to-event than they were to differ from other people. Additionally, individuals perceived the highest level of ESC over interpersonal stressors (events involving others) and the lowest amount of ESC over network stressors (events occurring to other people that were stressful for the individual).

The focus of paper 2 was on the diurnal rhythm of salivary cortisol and considerations for collecting the hormone in a method that is both reliable and valid. Four main problems were described for researchers wishing to collect salivary cortisol in a natural setting. The three parameters of salivary cortisol used in outcomes were the cortisol awakening response (CAR), the daily decline slope, and the area under the curve (AUC). Results showed that the four problem flags occurred on just over 12% of saliva collection days. Accounting for these flags resulted in within-person variation in the daily decline slope of cortisol raising to 70% (vs. 58% when not accounting for flags). Most importantly, by comparing results of the current study to previously published papers on salivary cortisol, researchers can be confident that participants can provide valid saliva samples even without face-to-face instructions.

By combining results found in papers 1 and 2, the third study examined the predictive effect of event-specific control on parameters of the diurnal rhythm of salivary cortisol. Event-specific control significantly predicted the cortisol daily decline slope such that events where individuals perceived lower ESC resulted in flatter slopes. There was also a significant interaction between age and ESC where younger individuals with low ESC had less steep slopes, but for older individuals ESC had no effect on their daily decline of cortisol.

The dataset used for the current analyses has an incredible amount of information that may contribute to this literature. For example, two characteristics of the stressful event were utilized for analyses, the type of event and the perceptions of control. It is very likely that many more characteristics are vital. When a participant acknowledges a stressful event occurred on any given interview day the next question asked is, “What happened”. The event is then transcribed verbatim. In addition, the participant is asked about the subjective severity of the event, how much anger, sadness, shame they were feeling, and the amount of risk (to daily routine, finances, self-esteem, etc) associated with the stressful event. From the transcribed event, trained coders rate the event for objective severity. The same technique could be used to obtain objective control, (i.e. how much control might the average person perceive in this situation). The main point here is that there are many possibilities.

Future directions can also concentrate on a broader array of outcomes, not limited to salivary cortisol. Physical symptoms, positive and negative affect, and measures of productivity are just a few daily measures that could be investigated using the current data. In keeping with physiological outcomes, in addition to cortisol, DHEA and alpha amylase are two more biomarkers that can be extracted from saliva. There are also data on more global health measures of the individual such as cardiovascular health, chronic illness, measures of inflammation (IL-6), and even functional MRIs to detect differences in brain activity.

Clearly, there are many possibilities moving forward and researchers in this area have only begun to scratch the surface. Hopefully, this paper will serve as an initial step to investigating event-specific perceptions of control. As technology continues to develop, obtaining perceptions of control over stressful events will become easier in relation to the timing of the event. Developing a more sophisticated measure of event-specific control and limiting the gap between the event and recall is the next step.

The chief contribution of this dissertation is the importance of including event-specific perceptions of control in the stress process. Trait or global measures of control, such as locus of control or self-efficacy, are not obsolete; however, ESC can contribute as much, if not more, in explaining variation in potential outcomes. The fact that "perceptions" or "feelings" of control can influence our physiology at the daily level should speak to the power of the mind-body connection.

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Hunt, J.E., **Banks, S.R**., Barber, B.L. (2004). Sports participation: Impact on positive youth development. *In Fisher, C. B. & Lerner, R. M. (Eds). Encyclopedia of applied developmental science. Thousand Oaks: Sage.*

SELECTED PRESENTATIONS

Banks, S.R., Almeida, D.M. (2007)**.** In the Driver's Seat? Daily Stressors and Perceived Control. Poster presented at the 60th annual scientific meeting of the Gerontological Society of America. San Francisco, CA.

Banks, S.R., Dmitrieva, N., Almeida, D.M. (2006)**.** What Dreams May Come: The Effects of Sleep on Daily Well-Being. Poster presented at the 59th annual scientific meeting of the Gerontological Society of America. Dallas, TX.

Banks, S.R. & Almeida, D.M. (2005). Reliability and validity of daily cortisol assessments in a non-experimental context. One paper of a symposium presented for the 58th annual scientific meeting of the Gerontological Society of America. New Orleans, LA.

Banks, S.R., Almeida, D.M. Wong, J., Weininger, A. (2004). For better, for worse, or both? Examining the links between daily stressors and positive events. Paper presented for the 57th annual scientific meeting of the Gerontological Society of America. Washington, DC.

Banks, S. R., Ridley, C. A., Cate, R. M., Busboom, A., Collins, D., Hunt, J. E., Lucero, A., Ellexson, B., & Ogolosky, B., Plush, R. (2003). Daily Stress and Dating Relationships. One paper of a symposium presented for the National Council on Family Relations for the 65th Annual Conference, Vancouver, BC, Canada.

HONORS, AWARDS, & SCHOLARSHIPS

8/2004 – 8/2007 – National Institute of Aging Fellowship. The Pennsylvania State University

8/2006 – American Psychological Association International travel award.

8/2003 – Cowden Fellowship – University of Arizona. Thesis Scholarship