Everyday Stress and Cortisol Reactivity: Exploring Self-Regulation at the Momentary, Daily, and Trait Level among First-Year College Students

by

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ABSTRACT

Daily life stressors and negative emotional experiences predict poor physical and psychological health. The stress response of the hypothalamic-pituitary-adrenal axis is a primary biological system through which stressful experiences impact health and well-being across development. Individuals differ in their capacity for self-regulation and utilize various coping strategies in response to stress. Everyday experiences and emotions are highly variable during adolescence, a time during which self-regulatory abilities may become particularly important for adapting to shifting social contexts. Many adolescents in the U.S. enter college after high school, a context characterized by new opportunities and challenges for self-regulation. Guided by biopsychosocial and daily process approaches, the current study explored everyday stress and negative affect (NA), cortisol reactivity, and self-regulation assessed at the momentary, daily, and trait level among a racially/ethnically and socioeconomically diverse sample of first-year college students ($N = 71$; $M_{age} = 18.85$; 23% male; 52% non-Hispanic White) who completed a modified ecological momentary assessment. It was expected that within-person increases in momentary stress level or NA would be associated with cortisol reactivity assessed in college students' naturalistic settings. It was predicted that these within-person associations would differ based on engagement coping responses assessed via momentary diary reports, by the range of engagement coping responses assessed via diary reports at the end of the day, and by higher trait levels of self-regulation assessed via standard self-report questionnaire. Within-person increases in momentary stress level were significantly associated with momentary elevations in cortisol only during moments characterized by greater than usual engagement coping efforts (i.e., within-person

increases). At a different level of analysis, within-person increases in momentary stress level were significantly associated with increases in cortisol only for those with low trait levels of coping efficacy and engagement coping. On average, within-person increases in momentary NA were significantly associated with cortisol reactivity. Tests of moderation revealed this momentary association was only significant for those with low trait levels of support-seeking coping.

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Introduction

Daily stressful events have been linked to physical symptoms and psychological distress among college students and adults (e.g., Almeida, 2005; Cohen, Gunthert, Butler, O'Neill, & Toplin, 2005; DeLongis, Folkman, & Lazarus, 1988; Kanner, Coyne, Schaefer, & Lazarus, 1981). Researchers have identified the stress response of the hypothalamic-pituitary-adrenal (HPA) axis as a primary biological system through which stress impacts health and well-being across development (e.g., Chrousos & Gold, 1992; Gunnar & Quevedo, 2007). Researchers have also examined how individuals differ in their capacity to regulate responses to stressful experiences in ways that maximize well-being, ranging from individual differences in self-regulatory abilities (Eisenberg, Hofer, Sulik, & Spinrad, 2014; Rothbart & Bates, 2006) to selecting various coping strategies when faced with a stressor (Compas, Connor-Smith, Saltzman, Thomsen, & Wadsworth, 2001; Pennebaker, Colder, & Sharp, 1990).

The ability to regulate responses to stress develops across the lifespan (Adam, Klimes-Dougan, & Gunnar, 2007; Losoya, Eisenberg, & Fabes, 1998). From a developmental systems perspective (Lerner, 2006), times of transition may be particularly sensitive periods of development when social contexts interact with behavioral and biological processes related to stress and regulation. The transition from adolescence into adulthood is one such period (Masten, 2004; Schulenberg, Sameroff, & Cicchetti, 2004; Steinberg, Dahl, Keating, & Masten, 2004), a time during which young adults exhibit more extreme levels of emotion in response to stress compared to middle-aged and older adults (Neupert, Almeida, & Turk, 2007), navigate shifting sources of social support from friends and family (Larose & Boivin, 1998), and experience normal neurobiological changes in the still-developing prefrontal cortex and limbic brain regions (Casey, Jones, & Hare, 2008; Spear, 2000). Evidence also suggests that young adults exhibit heightened HPA axis responses to stress compared to children and elderly adults (Kudielka, Buske-Kirschbaum, Hellhammer, & Kirschbaum, 2004).

Many adolescents in the U.S. pursue higher education as they transition to adulthood (U.S. Bureau of Labor Statistics, 2013). Entering the college environment provides opportunities for adaptation and growth within a new context (Arnett, 2000, 2007). However, these adolescents also face added stress in this new context, including increased academic demands, added financial responsibilities, and new temptations for risky behavior (Howard, Schiraldi, Pineda, & Campanella, 2006; Nguyen, Walters, Wyatt, & DeJong, 2011; Schulenberg & Zarrett, 2006). The relevance of considering everyday stress and self-regulation specifically for these adolescents who enter the college environment is clear: college students report poor sleep (Lund, Reider, Whiting, & Prichard, 2010), elevated rates of alcohol use (Carter, Brandon, & Goldman, 2010), and concerning rates of suicidal ideation (Wilcox et al., 2011).

Adolescents who enter the college context face daily challenges, but the impact of these challenges on health and adjustment may depend on how they self-regulate or cope with stress. Within the coping literature, researchers have used a variety of assessment tools to examine daily stressors and coping strategies among adolescents and college students, including retrospective self-report inventories, checklists of coping responses, interviews, and behavioral observation (see Compas et al., 2001, for review). As researchers have come to better understand the strengths and limitations of these respective methods, some have increasingly argued for within-person, process-oriented methods that examine stress and coping intensely over time (Affleck, Zautra, Tennen, & Armeli, 1999; DeLongis & Holtzman, 2005; Tennen, Affleck, Armeli, & Carney, 2000). Ecological momentary assessment[1] (EMA; Stone & Shiffman, 1994) protocols require participants to respond to brief questions at random points throughout their typical days, either through the use of paper-and-pencil diaries or more sophisticated electronic response formats. These methods reduce retrospective recall and memory biases, facilitate ecological validity, and allow researchers to make within-person comparisons and examine temporal dynamics (Smyth & Heron, 2014). Unlike traditional survey methods, data gathered from EMA studies have the ability to discriminate changes in stress and coping associated with minor daily events (Stone et al., 1998).

More recently, developmental scientists have started to pair the collection of salivary biomarkers (e.g., cortisol) with EMA designs in order to objectively measure the HPA axis response to everyday stress among adolescents and college students within their natural environments (e.g., Adam, 2006; Doane & Adam, 2010; Doane & Zeiders, 2014). Although more researchers have started to incorporate physiological assessments into study designs, the literature regarding within-person changes in everyday stress and coping responses as they relate to HPA axis reactivity among adolescents in the real-world college context remains limited. Even less is known about how coping strategies

[1]Ecological momentary assessment (EMA) methods are also known as the experience sampling method (ESM; Larson & Csikszentmihalyi, 1983). Both EMA and ESM involve participant self-report at random points throughout days of typical life. EMA has origins in behavioral medicine whereas ESM originated in psychological research.

assessed at the momentary or daily level compare to trait-level indicators of self-regulation as moderators of the HPA axis response to everyday stress. Comparing these levels of analysis (e.g., momentary, daily, and trait) is critical to extend previous findings from laboratory studies and better approximate how physiological reactivity to stress operates in naturalistic environments more relevant to the everyday lives of college students. Naturalistic studies allow researchers to examine reactivity and responses to experiences that actually occur in adolescents' lives without disrupting their typical routine by bringing them to a lab. Findings from such work have the potential to readily inform intervention and prevention programs aimed at improving how adolescents manage accumulating daily hassles when starting college (e.g., Pennebaker et al., 1990). Researchers, clinicians, and university administrators have identified a growing need for college transition programs that promote effective self-regulation skills and enhance the first-year experience for college students (e.g., Barefoot et al., 2005; Deckro et al., 2002; Mattanah et al., 2010; Steinhardt & Dolbier, 2008).

As such, the goals of this thesis are to examine: 1) whether within-person increases in everyday stress are associated with cortisol reactivity among adolescents during their first year of college, and 2) how moment-to-moment and day-to-day differences in coping responses and individual differences in self-regulatory abilities (e.g., effortful control, coping) during the first year of college may moderate the association between everyday stress and cortisol reactivity. First, this thesis provides a brief theoretical overview that serves as a framework and guides the research questions and hypotheses. Second, relevant empirical findings are reviewed in order to summarize past results and identify limitations of available literature on daily stressful experiences, cortisol reactivity, self-regulation, and coping, with a particular emphasis on research within the developmental period of adolescence for those who transition to the social context of college. Third, the research questions and expected outcomes are detailed. Fourth, the methods for investigating these questions and the analytic plan are detailed. Fifth, model results are presented. Finally, findings are interpreted in light of the theoretical framework and available empirical literature, limitations and future directions are discussed, and conclusions are drawn.

Theoretical Overview

The Biopsychosocial Model of Stress (Bernard & Krupat, 1994) outlines three components of stress and adaptation: 1) external or environmental stimuli, 2) internal or physiological reactions to stress, and 3) reciprocal relations between external and internal processes. This model highlights the importance of stress appraisal: how individuals perceive stressful events in their lives and how this perception activates physiological responses to external stimuli. Ultimately, the model serves as a framework to explore the pathways through which biological, psychological, and social factors impact health and adjustment. Researchers have extended this model to account for developmental changes in how adolescents perceive and manage stress while taking into account the interrelatedness of biological, psychological, and social aspects of development (e.g., Compas, Hinden, & Gerhardt, 1995; Lerner, 1985). The model has also been applied to college students with particular interest in how biological, psychological, and social components of stress contribute to well-being for adolescents immersed in the social context of college life (Howard et al., 2006). The present research draws from the three primary components outlined in the Biopsychosocial Model of Stress: 1) daily stressors experienced by adolescents in their first year of college (environmental stimuli), 2) cortisol reactivity and self-regulatory abilities (physiological and internal reactions to stress), and 3) associations among stress, cortisol reactivity, and self-regulation (relations between external and internal processes).

To best capture psychosocial and biological components of stress, the present research utilized within-person, process-oriented methods that examine stress and coping intensely over time through the use of EMA (e.g., Affleck et al., 1999; Stone & Shiffman, 1994; Tennen et al., 2000). By comparing an individual's level of perceived stress and report of coping responses in a given situation to his/her own average level of perceived stress and coping responses across several days, researchers are better able to capture within-person variability in stress and coping processes closer to their real-time occurrence. This approach differs from the large body of work relying on global self-report inventories to capture retrospective reports of how adolescents typically respond to stress in general or how they *would* respond to a hypothetical stressor (e.g., Hampel & Petermann, 2006; Seiffge-Krenke, 2000). Both approaches have contributed to the literature in important ways. However, by design, daily process methods can better accommodate the temporal patterning of dynamic stress processes, reduce recall error of events and experiences, and data can demonstrate improved reliability and validity (DeLongis & Holtzman, 2005). Trait-like measures are poor predictors of coping responses captured by daily reports: studies using both methods reported only 26% and

37% shared variance between the two (Ptacek, Smith, Espe, & Raffety, 1994; Smith, Leffingwell, & Ptacek, 1999). Another study reported that coping style at the trait level (i.e., self-report of typical responses to hypothetically stressful events) and an aggregated momentary measure from diary reports only shared 0-12% of their variance across 16 types of coping responses (Schwartz, Neale, Marco, Shiffman, & Stone, 1999). As such, the present research used daily process methods to examine within-person differences in everyday stress and coping responses assessed at the momentary and daily level. It is still unclear how these reports compare to trait-level indicators of self-regulation in relation to cortisol reactivity among college students. The following literature review highlights available evidence using similar daily process methods, but also includes key findings from research using traditional retrospective surveys and/or laboratory stress tasks.

Everyday Stress

Almost fifty years ago, Lazarus (1966) proposed that stress occurs when perceived demands from the environment exceed an individual's ability to cope with them. Over time, researchers have advanced this definition to consider stress as a process, including a stimulus, appraisal, and response (Cohen, Kessler, & Underwood, 1995; Miller, Chen, & Parker, 2011). By identifying stimuli from the environment and perceiving these stimuli as threatening and unmanageable, individuals experience a psychological state of stress that leads to a series of behavioral and biological responses (Lazarus & Folkman, 1984). Developmental researchers have expanded this model of stress to include demands that come from internal sources such as physiological changes and development, in addition to external environmental stimuli (Bernard & Krupat, 1994; Compas, 1987; Johnson, 1982).

Researchers typically differentiate between two broad categories of stressors across development: acute and chronic. Both acute and chronic stressors have been linked to poor health and adjustment, ranging from flu symptoms to depression (e.g., Compas, 1987; DeLongis et al., 1988; Grant et al., 2003; Gunnar & Quevado, 2007). There is a rich tradition in developmental psychology to consider the enduring effects of chronic stress, such as early life adversity and recurring stressors experienced by those growing up in poverty (e.g., Blair & Raver, 2012; Miller et al., 2011). However, researchers have also considered the health relevance of acute stressors that change day to day and involve seemingly small disruptions to an individual's status quo (e.g., DeLongis et al., 1988; Hanson & Chen, 2010).

Kanner, Coyne, Schaefer, and Lazarus (1981) were among the first to examine how relatively minor events of everyday life ("daily hassles") relate to psychological problems. In a sample of adults (45-64 years old), daily hassles accounted for significant variance in psychological symptoms over and above major life events (Kanner et al., 1981). In another study with a sample of married couples (35-45 years old), everyday stress was related to both concurrent and next-day health problems, including flu, sore throat, headaches, and backaches (DeLongis et al., 1988). Evidence from another study suggested that daily life events mediated the relation between major negative events and psychological symptomatology in a sample of adolescents transitioning from high school into college (Wagner, Compas, & Howell, 1988). Taken together, these findings provide support for the link between everyday stress and poor physical and psychological health. Moving forward, there is great potential to focus on everyday stress within a developmental framework to better understand how individuals perceive and respond to daily demands characteristic of their specific developmental context.

Everyday stress among adolescents. Adolescence is a dynamic developmental period characterized by shifting social contexts that present opportunities as well as challenges (e.g., Masten, 2004; Parker, Rubin, Erath, Wojslawowicz, & Buskirk, 2006; Rubin, Bukowski, Parker, & Bowker, 2006). Most adolescents begin to spend less time with family members (Larson & Richards, 1991) while experiencing increases in social support from friends (De Goede, Brange, & Meeus, 2009; Way & Greene, 2006). One study showed that adolescents spent almost a third of their waking hours with peers (double the amount of time spent with family members) by the time they reached high school (Csikszentmihalyi & Larson, 1984). This dramatic shift in social context coincides with prominent developmental transformations in brain regions responsible for social-affective processing during adolescence (Crone & Dahl, 2010; Spear, 2000), which may contribute to increased sensitivity and vulnerability to social and emotional sources of stress. Indeed, adolescents perceive more stressors compared to children and show increased negative mood and mood variability (Colten & Gore, 1991; Compas, Hinden, & Gerhardt, 1995; Larson & Seepersad, 2003), which suggests this group may be particularly vulnerable to stress. However, there are also important age-related increases in adolescents' capacity for cognitive control (Huizinga, Dolan, & van der Molen, 2006; Spear, 2000) and emotion regulation (Allen & Land, 1999). In sum, although adolescents experience a high degree of variability in everyday social and emotional experiences, they also mature cognitively and learn to better self-regulate their emotions in response to stress during this developmental period.

Most adolescents are equipped with the resources to adapt effectively to stressful demands. However, other adolescents who lack protective resources may be particularly vulnerable to adjustment problems (Cicchetti & Rogosch, 2002; Masten, 2004). Rates of onset for depression and other emotional disorders increase dramatically in adolescence (Burke, Burke, Rae, & Regier, 1991) and many adult episodes of major depressive disorder have their initial onset during the adolescent years (Costello et al., 2002). Both acute and chronic stressors are related to depressive symptoms in adolescence and prospectively predict internalizing problems later in life (see Grant et al., 2004, for review). In a diary study, highly anxious adolescents reported higher rates of daily stress (Henker, Whalen, Jamner, & Delfino, 2002). Findings from a study using traditional self-report measures indicated that adolescents who reported more negative daily events were more likely to have a lower grade point average (Windle & Windle, 1996). In another diary study of adolescents, higher daily stress was associated with shorter sleep duration that night, which in turn was related to higher stress the next day (Doane & Thurston, 2014). Together these findings generally indicate that both persistent (chronic) and daily stressors are related to poor adolescent health and adjustment. This association between stress and adjustment among adolescents is likely reciprocal (e.g., Kim, Conger, Elder, & Lorenz, 2003).

Everyday stress for adolescents in the college context. Adolescents continue to compete with added demands across multiple domains as they begin the transition to adulthood. Arnett (2000) has highlighted the importance of examining the developmental transition that occurs roughly between the ages of 18 and 25 in industrialized societies. According to Arnett (2000, 2007), these emerging adults benefit from growing social cognitive maturity during this time, as well as limited family and work obligations. Findings from a meta-analysis demonstrated that the largest changes in personality occur between the ages of 18 and 30: on average, young adults become more socially dominant, more conscientious, and less neurotic as they age (Roberts et al., 2006). Other developmental researchers have described the emergence of a prolonged transition period during which adolescents become full-fledged adults in many societies (Steinberg et al., 2004). Some have argued this time between adolescence and adulthood may be one of the most critical normative developmental transitions because of pervasive and simultaneous changes in context and social roles (Schulenberg et al., 2004). During this unique time, adolescents can experience substantial changes in nearly all domains of life (e.g., school, work, interpersonal relationships, living situation) within a few years, which contributes to a great diversity of life paths (Cohen, Kasen, Chen, Hartmark, & Gordon, 2003).

In the U.S., many adolescents pursue a college education as they begin the transition to adulthood. A recent nationally representative survey indicated that 66% of adolescents who graduated from high school enrolled in colleges or universities by the following fall. Of these, approximately 60% began attending four-year institutions (U.S. Bureau of Labor Statistics, 2013). For these adolescents, the college environment can provide a social context for exploring options and building new interpersonal relationships (e.g., Swenson, Nordstrom, & Hiester, 2008). However, the college context also introduces a host of unique stressors, including increased academic pressure, dysregulated sleep patterns, and opportunities for risky behavior (Carter et al., 2010; Lund et al., 2010; Ross, Niebling, & Heckert, 1999; Schulenberg & Zarrett, 2006; Struthers, Perry, & Menec, 2000). In a study of over 1000 students at a Midwestern university, college students reported that academic stress negatively impacted their sleep, with 60% of the sample characterized as poor-quality sleepers (e.g., trouble falling asleep, waking up in the middle of the night; Lund et al., 2010). A review of 18 direct comparison studies found that college students drink more frequently than non-college peers and are also at heightened risk for alcohol abuse and dependence (Carter et al., 2010). Daily diary studies have demonstrated that college students are more likely to drink on days they perceive as stressful (e.g., Park, Armeli, & Tennen, 2004). Perhaps most concerning, large survey studies estimate that 10-12% of students seriously consider suicide while in college (Kisch, Leino, & Silverman, 2005; Wilcox et al., 2010); suicide is the second leading cause of death among college-age young adults in the U.S. (Centers for Disease Control and Prevention, 2009). Given these problems, it comes as no surprise that university officials have engaged in widespread efforts to improve students' first-year experience (Upcraft, Gardner, & Barefoot, 2004). The first year of college provides a critical stage at which to intervene in order to promote effective stress management techniques for adolescents who are adjusting to a new context (e.g., Barefoot, 2005).

Cortisol Reactivity

The stress response of the HPA axis is a potential mechanism through which life experiences impact socioemotional development and adjustment (Adam et al., 2007; Chrousos & Gold, 1992; Johnson, Karmilaris, Chrousos, & Gold, 1992). The HPA axis is one of the body's major stress response systems, recruiting the body's resources to react to stressors and stimulating the release of the steroid hormone cortisol (de Kloet, 2004). Cortisol is produced in the body through a series of steps: corticotropin-releasing hormone and vasopressin released by the paraventricular nucleus of the hypothalamus travel through the blood to the anterior pituitary, where they stimulate production of adrenocorticotropic hormone, which in turn binds to receptors on the adrenal cortex to stimulate the production and release of cortisol (e.g., Herman & Cullinan, 1997; Johnson et al., 1992). Cortisol levels reach their peak in saliva approximately 20-25 minutes following a stressor but take up to an hour to return to baseline levels (see Adam, 2012, for review). In coordination with other biological systems, including the autonomic nervous system (e.g., increases in heart rate, blood pressure), the HPA axis production of cortisol represents a series of events that allow for adaptive behavioral responses during stressful situations (Chrousos & Gold, 1992). Cortisol reactivity is necessary in order to cope with acute life stressors but repeated or chronic activation of this stress response can lead to deleterious physical and mental health outcomes (McEwen, 2004; Miller, Chen, & Zhou, 2007), particularly during sensitive periods of rapid brain development (Danese & McEwen, 2012; Gunnar & Quevedo, 2007).

To assess cortisol reactivity to psychological stressors, researchers have typically relied on laboratory tasks designed to reliably activate the HPA axis response under controlled conditions (Dickerson & Kemeny, 2004). One of the most common ways to measure cortisol is through saliva, which can be obtained without trained medical personnel and provides a reliable and valid indicator of serum or plasma cortisol concentration (Kirschbaum & Hellhammer, 1989; Woodside, Winter, & Fisman, 1991). In one of the most standard and widely-replicated lab stress paradigms, the Trier Social Stress Test (TSST), participants give a public speech and perform challenging mental arithmetic in front of two confederate "judges" while being video recorded (Kirschbaum, Pirke, & Hellhammer, 1993). In the TSST and similar stress tasks, participants provide a baseline measure of saliva followed by additional samples throughout the task that allow researchers to model cortisol reactivity and recovery patterns. A meta-analysis of studies using such lab tasks revealed that uncontrollable and socially evaluative stressors most consistently activate the cortisol response (Dickerson & Kemeny, 2004).

Researchers using lab tasks have explored individual differences in cortisol reactivity across a wide array of samples and stressors, including gender differences among adolescents and adults (Kirschbaum, Wüst, & Hellhammer, 1992), developmental differences elicited by socially evaluative tasks among adolescents (Stroud et al., 2009), and differences based on cultural orientation (i.e., independence vs. interdependence) for first-generation college students (Stephens, Townsend, Markus, & Phillips, 2012). In sum, researchers have accumulated evidence to suggest there are meaningful individual differences in the HPA axis response to stress. To be clear, increases in cortisol in response to a stressful experience reflect a normative and adaptive stress response pattern (Dickerson & Kemeny, 2004; Kirschbaum & Hellhammer, 1994; McEwen, 2004). However, researchers have identified the negative health correlates of routinely exaggerated (i.e., higher than normal) cortisol levels in response to stress, including suppressed immune function, the development of chronic diseases such as hypertension (McEwen, 1998), and major depression (e.g., Parker, Schatzberg, & Lyons, 2003). In contrast, researchers have found attenuated (i.e., lower than normal, but not blunted or static) cortisol levels for young adult men who were in the presence of a romantic partner during a stressful task (Kirschbaum, Klauer, Filipp, & Hellhammer, 1995) and for college students who exhibited a greater range of observed coping responses (e.g., a more flexible coping profile) during a stressful task (Roubinov, Hagan, & Luecken, 2012). Laboratory studies have allowed researchers to examine between-person differences in cortisol reactivity under controlled conditions, but there is also a need to consider how cortisol reactivity differs within individuals for developmentally salient and ecologically valid stressors.

Cortisol is also necessary for daily physiological functioning, including metabolic processes and the immune system (Lovallo, 2005). In addition to its role in stress reactivity, cortisol is released throughout the day in a typical pattern characterized by relatively high levels at waking, a dramatic increase 30 minutes later (the cortisol awakening response, CAR), and then a general decrease across the day with lowest levels around midnight (e.g., Adam & Kumari, 2009; Pruessner et al., 1997). Across several studies researchers have documented that adolescents also exhibit this normative diurnal pattern (Adam, 2006; Doane & Adam, 2010; Doane & Zeiders, 2014). However, adolescents also experience important developmental changes in HPA activity coinciding with pubertal maturation, including heightened biological responsiveness to stress (e.g., Dahl & Gunnar, 2009). Specifically, there are puberty-related increases in basal cortisol levels (Gunnar et al., 2009; Kiess et al., 1995) and adolescents 13-17 years of age exhibit heightened cortisol reactivity to stress elicited by social evaluation compared to younger children 7-12 years of age (Stroud et al., 2009).

Cortisol reactivity in naturalistic settings. One of the first studies to measure salivary cortisol using naturalistic methods found that cortisol reactivity to the stress of a lab task did not predict reactivity to stressful events in daily life for a sample of adult men (van Eck, Nicolson, Berkhof, & Sulon, 1996a). A follow-up study found that stressful daily events were associated with increased cortisol levels (van Eck, Berkhof, Nicolson, & Sulon, 1996b). These preliminary findings were among the first to suggest that cortisol reactivity measured in a controlled lab setting might not generalize to responses to daily life experiences. Since then, more researchers have focused on the physiological correlates of everyday stress by using ambulatory assessment of salivary cortisol paired with EMA to better estimate real-world reactions to stress (for reviews see Granger et al., 2012; Kudielka, Gierens, Hellhammer, Wüst, & Schlotz, 2012). Reactivity using this method refers to within-person elevations in cortisol level from an individual's diurnal rhythm concurrently with diary reports of stress and mood rather than the detailed baseline, response, and recovery cortisol profiles used in lab studies (e.g., Adam, 2006). Using naturalistic methods, researchers have found that daily stressors and experiences of negative affect were associated with increased cortisol levels among healthy adults (Jacobs et al., 2007; Smyth et al., 1998). Interestingly, adults meeting criteria for major depressive disorder exhibited blunted cortisol reactivity (i.e., no increase in cortisol levels) in response to negative daily events (Peeters, Nicholson, & Berkhof, 2003).

Researchers have explored a similar association between everyday stress and cortisol reactivity among adolescents and college students. Adam (2006) collected seven sets of saliva samples and diary reports across two days from adolescents ranging in age from 13 to 17. Within-person increases in negative mood (worry/stress) were associated with increases in cortisol and this association was stronger for older adolescents. Doane and Adam (2010) used similar methods in a sample of older adolescents (17-20 years old) and found that cortisol responses to daily experiences differed based on a trait indicator of chronic stress. Within-person increases in momentary-reported loneliness were associated with increases in cortisol for those adolescents who reported higher chronic interpersonal stress. Doane and Zeiders (2014) recently documented contextual moderators of the relation between daily experiences and cortisol among adolescents preparing to transition to college. Within-person increases in momentary-reported negative affect were associated with increases in cortisol for those perceiving higher everyday experiences of discrimination, whereas increases in negative affect were not associated with increases in cortisol for those reporting higher perceived social support from friends. Together these studies illustrate how aspects related to adolescents' developmental and social context (e.g., worry, social support from friends) contribute to their daily psychophysiological experiences of stress. More specifically, these findings indicate that some adolescents (e.g., those with less chronic stress, those who perceive more social support) exhibit attenuated cortisol reactivity to stress or negative experiences during the day, which may reflect their ability to better self-regulate in response to stress.

Researchers have also explored cortisol reactivity to everyday stress specifically for adolescents who have entered the college context. In a naturalistic study of 28 college students, cortisol levels increased in anticipation of a real-life multiple-choice exam (Nicolson, 1992). In a larger study of over 700 college students, cortisol levels were higher on the day of an exam compared to a control day (Verschoor & Markus, 2011). Another study of 44 female college students found that cortisol levels were significantly higher when individuals were alone throughout the day (Matias, Nicolson, & Freire, 2011). Finally, another naturalistic study involving college students demonstrated the importance of developmental and psychosocial influences on stress reactivity: college students who reported receiving less parental warmth during childhood had higher cortisol on days when they perceived a more severe stressor, compared to those who received more parental warmth during childhood (Hanson & Chen, 2010). Findings from these studies illustrate how daily stressors characteristic of the college environment (e.g., exams) are linked to cortisol reactivity, but the ways adolescents differ in their abilities to regulate physiological stress responses in this context remains unclear. Naturalistic assessment of cortisol reactivity among college students provides an opportunity to explore the various ways adolescents self-regulate when faced with daily challenges in the college context.

Self-Regulation and Coping: Definitions and Dimensions

Constitutionally based individual differences in child and adolescent temperament are typically considered within two broad categories: reactivity and self-regulation (Rothbart & Bates, 2006). Reactivity includes relatively involuntary emotional responses to change in the external and internal environment and physiological responses (e.g., cortisol reactivity). Self-regulation encompasses volitional processes that modulate reactivity to experience (Rothbart & Bates, 2006). Researchers have defined and referred to self-regulation in a variety of ways (including overlapping definitions with emotion regulation, see Cole, Martin, & Dennis, 2004). Eisenberg, Hofer, and Vaughn (2007) define *emotion-related self-regulation* as "processes used to manage and change if, when and how…one experiences emotions and emotion-related motivational and physiological states, as well as how emotions are expressed behaviorally" (pp. 288). This definition is consistent with other theoretical work on emotion regulation (e.g., Gross, 2014). Examples of self-regulatory processes include changing emotions, selecting or changing situations to prevent or initiate emotional responses, modifying how one views the significance of an event, and expressing emotion behaviorally (Eisenberg et al., 2014).

One aspect of self-regulation is effortful control: the efficiency of executive attention, including the ability to inhibit a dominant response and/or activate a subdominant response, to plan, and to detect errors (Rothbart & Bates, 2006). Effortful control represents abilities to voluntarily shift or focus attention and inhibit or activate behaviors to meet environmental demands (Eisenberg, Smith, & Spinrad, 2011; Rothbart & Bates, 2006). Capacities for effortful control, such as correcting errors and planning new actions, begin to develop in the first few years of life (Posner & Rothbart, 1998) and are fairly stable across childhood and adolescence (Eisenberg et al., 2005; Kochanska & Knaack, 2003). However, evidence also suggests there are age-related increases in certain aspects of effortful control (e.g., inhibitory control) and emotion regulation that continue into adulthood (e.g., Williams, Ponesse, Schachar, Logan, & Tannock, 1999; Zimmerman & Iwanski, 2014). Important for this thesis, capacities for effortful control are used to cope actively with stress (Compas et al., 2001; Eisenberg et al., 2011).

Coping responses are often considered a subset of self-regulatory processes employed specifically when one is under stress (Compas et al., 2001; Eisenberg, Fabes, & Guthrie, 1997). A greater diversity and flexibility in range of coping responses becomes available during middle childhood and adolescence (Losoya et al., 1998). Coping is an ongoing dynamic process including cognitive and behavioral efforts to manage both external and internal demands appraised as exceeding a person's resources (Lazarus & Folkman, 1984). The relative effectiveness of coping efforts is inherently dependent on the context in which they are used, otherwise known as the "match" or "goodness of fit" between stress and coping processes (e.g., Folkman & Lazarus, 1980; Folkman, Schaefer, & Lazarus, 1979). A wealth of previous research from a cognitive perspective has established that the utility of various coping responses depends upon appraisals of the stressor as controllable or uncontrollable (e.g., Folkman & Lazarus, 1980; Stone & Neale, 1984). For example, psychological symptoms (e.g., depression, anxiety) were higher among college students when there was poor fit between appraisals and coping (attempting to change an uncontrollable stressor), yet lower when there was good fit (adapting to an uncontrollable stressor; Forsythe & Compas, 1987). Adolescents may cope with stress through voluntary as well as involuntary (not intentional) responses (Eisenberg et al., 1997; Skinner & Wellborn, 1994), but many coping researchers have focused on voluntary (deliberate) methods in order to better understand how adolescents' purposeful efforts to manage stress may be improved (Compas et al., 2001). When referring to coping responses, this thesis relies on the definition provided by Compas et al. (2001): "conscious volitional efforts to regulate emotion, cognition, behavior, physiology, and the environment in response to stressful events or circumstances" (pp. 89).

Researchers have proposed a variety of coping dimensions in an attempt to best categorize and examine the effectiveness of different responses that children and adolescents use to handle stress (see Compas et al., 2001, for review). These dimensions range from problem-focused vs. emotion-focused (e.g., Folkman & Lazarus, 1985), active vs. passive (e.g., Walker, Smith, Garber, & Van Slyke, 1997) and less commonly, adaptive vs. maladaptive (e.g., Meyer, 2001). From a developmental perspective, Eisenberg et al. (1997) recognized three aspects of coping (including both voluntary and involuntary responses) in children: emotion-focused (attempts to directly regulate emotion), problem-focused (attempts to regulate the situation), and behavior regulation (attempts to regulate emotionally driven behavior). Based on a factor analysis involving three samples of adolescents, including a sample of college students, Connor-Smith, Compas, Wadsworth, Thomsen, and Saltzman (2000) provided evidence for two dimensions of *voluntary* coping responses: engagement and disengagement. Engagement coping efforts are directed toward a stressor or one's reactions to the stressor and reflect approach responses, whereas disengagement coping efforts are oriented away from a stressor and reflect avoidance responses (e.g., emotional numbing, inaction). Within engagement coping, primary control strategies are those efforts aimed directly at altering the stressor or one's emotional response to the stressor, including problem-solving, emotional regulation, and emotional expression. Within engagement coping an additional dimension of secondary control strategies comprise efforts to adapt to the problem, including acceptance, cognitive restructuring, positive thinking, and distraction (Compas et al., 2001; Connor-Smith et al., 2000). For the purposes of this thesis, coping will refer to the subset of broader self-regulatory processes that involve voluntary responses to stress mapping on to Connor-Smith et al.'s (2000) dimensions, given theoretical and empirical support for this model among adolescents.

Effortful control and cortisol reactivity. As of yet, no researchers have examined the relation between effortful control and cortisol reactivity among college students. However, available literature points to the important role that effortful control plays in predicting adaptation and adjustment across development. Longitudinal studies generally indicate that higher effortful control predicts positive socioemotional development in childhood, including higher social competence (Eisenberg et al., 2011), better social cognition (Flynn, 2007), fewer externalizing problems (Eisenberg, Spinrad, & Eggum, 2010), better school outcomes (Eisenberg, Valiente, & Eggum, 2010), and higher sympathy (Eisenberg et al., 2007). Relatively less evidence is available for the link between effortful control and adjustment among adolescents and young adults, but data generally indicate a similar pattern of association. Less effective emotion regulation was associated with higher depressive symptoms and problem behavior in a sample of adolescents (Silk, Steinberg, & Morris, 2003). In a study of adolescents transitioning to college, more effective emotion regulation in high school prospectively predicted better social adjustment in college (Srivastava, Tamir, McGonigal, John, & Gross, 2009). In a recent longitudinal study of emerging adults, higher effortful control at age 22 predicted higher subjective well-being and lower depression and anxiety a year later (Fosco, Caruthers, & Dishion, 2012). Based on this literature, adolescents higher in effortful control would be expected to have an advantage with adapting effectively to everyday stress in the college environment.

Research exploring relations between effortful control and various indices of cortisol activity is still in its early stages, though, with most of this work focusing on younger children. In general, effortful control has been inversely related to cortisol (morning levels, baseline levels, or reactivity to a frustrating task) among preschoolers (Gunnar, Sebanc, Tout, Donzella, & van Dulmen, 2003; Gunnar, Tout, de Haan, Pierce, & Stansbury, 1997; Turner-Cobb, Rixon, & Jessop, 2008). In contrast, one study of preschoolers found that maternal report of effortful control was positively related to cortisol reactivity to a frustrating task (Spinrad et al., 2009). In a sample of adolescents (14-16 years old), cortisol reactivity to the TSST was associated with problems regulating anger for those who also retrospectively reported higher maltreatment during childhood (Cook, Chaplin, Sinha, Tebes, & Mayes, 2012). In another recent study, effortful control assessed while adolescents were in high school prospectively predicted a steeper average decline in daily cortisol output after transitioning to college (Doane, Taylor, Sladek, & Eisenberg, in preparation), a physiological pattern considered to reflect effective adaptation to one's environment (Miller et al., 2007).

Ego resiliency and cortisol reactivity. Ego resiliency is a personality characteristic that reflects adaptability to environmental stress and change (Block & Block, 1980). Individuals with high ego resiliency are able to adapt to changing situations, shift their behavior accordingly, and flexibly use problem-solving strategies (Block & Block, 2006). Findings from research in childhood indicate that effortful control likely contributes to the development of ego resiliency (e.g., Eisenberg et al., 2003; Taylor, Eisenberg, Spinrad, & Widaman, 2013). In adolescence and young adulthood, ego resiliency has been linked with lower externalizing and internalizing problems (Hofer, Eisenberg, & Reiser, 2010), greater perceived social support from family (Taylor, Doane, & Eisenberg, 2014) and greater prosocialty (Alessandri et al., 2014).

Much like the literature on effortful control, research examining ego resiliency and cortisol reactivity has focused on early childhood. In a study of five-year-old children, ego resiliency moderated cortisol responses to negative parent-child interactions (Smeekens, Riksen-Walraven, & van Bakel, 2007). Children high on ego resiliency did *not* exhibit significant increases in cortisol during a home parent emotional interaction, whereas children low on ego resiliency did show significant cortisol increases. In a more relevant but notably small study of 23 college students, those higher on ego resiliency exhibited greater autonomic activation (cardiac activity) in anticipation of a real-world examination and greater autonomic regulation (higher vagal tone) during recovery, suggesting that ego resiliency may contribute to both stress reactivity and regulation among college students (Spangler, 1997). However, ego resiliency was not linked to cortisol reactivity or recovery in the same study.

Coping efficacy and cortisol reactivity. In addition to how adolescents self-regulate and cope with stress, researchers have examined coping efficacy – the *belief* that one can deal with the demands made and emotion aroused by a situation, including confidence in how stress has been dealt with in the past and how it can be handled in the future (Sandler, Tein, Mehta, Wolchik, & Ayers, 2000). The construct of coping efficacy is also known as coping potential (Lazarus & Folkman, 1984), part of the secondary appraisal process during which individuals evaluate whether they can manage stressful demands in order to be protected from threats to well-being. Following this framework, coping efficacy has commonly been examined as a mediator through which coping efforts lead to adjustment. In one longitudinal study of nine- to twelve-year old children of divorce, active coping prospectively predicted coping efficacy, which in turn was associated with lower internalizing problems (Sandler et al., 2000). Similarly, coping efficacy mediated the link between ecological risk (e.g., stressful life events) and depressive symptoms in a sample of adolescents (Prelow, Weaver, & Swenson, 2006).

Broadly, coping efficacy has been associated with successfully adapting to various stressors, including trauma and daily pain (Benight et al., 1997; Keefe et al., 1997; Massey, Garnefski, Gebhardt, & van der Leeden, 2009). As of yet, there is no available empirical literature exploring coping efficacy as a moderator of cortisol reactivity. In a recent study, coping efficacy significantly moderated the association between longitudinal changes in loneliness across the college transition (a salient source of psychosocial stress during this time) and diurnal cortisol regulation in the college environment (Drake, Sladek, & Doane, in press). Adolescents who reported increased loneliness across the transition and low levels of coping efficacy exhibited significantly flatter diurnal cortisol slopes in college compared to those with high levels of coping efficacy. Although the findings from this recent study do not directly address the potential role of coping efficacy in modulating cortisol reactivity to everyday stress, they do provide preliminary evidence that HPA axis activity is sensitive to adolescents' beliefs in their ability to handle the demands of stressful situations.

Together, the above studies examining effortful control, ego resiliency, and coping efficacy span a wide range of developmental contexts and exemplify the diverse ways researchers choose to measure cortisol activity in both controlled and naturalistic settings. Although the use of different indicators of cortisol (e.g., waking levels, reactivity, diurnal rhythm) has revealed various patterns of associations (including no association), a general trend suggests that individual differences in self-regulation relate to cortisol reactivity and daily patterning. There is great potential to explore whether these individual differences moderate cortisol responses to stress during college in order to better understand why indices of self-regulation generally predict better adjustment in this context.

Coping and cortisol reactivity in naturalistic settings. Prior work has examined the link between coping and cortisol activity, with evidence that a coping style favoring engagement may be associated with less overall cortisol output across the day in older adults (O'Donnell, Badrick, Kumari, & Steptoe, 2008). However, evidence from other studies illustrates how measures of trait coping or coping style do not accurately predict individuals' actual coping strategies when reporting perceived stress in real life (Ptacek et al., 1994; Schwartz et al., 1999; Smith et al., 1999). Very few studies have utilized EMA designs to examine within-person differences in coping in order to determine how different ways of responding to stress might alter cortisol reactivity in naturalistic settings. Using these methods may be particularly informative given the recent move to consider the range of coping responses individuals use to manage stress (i.e., coping flexibility), rather than analyzing single types of responding (Cheng, 2001; Folkman & Moskowitz, 2004). For example, college students' self-reported coping strategies were unrelated to cortisol reactivity to a lab-based stressor task, but a greater range of observed responses was related to attenuated cortisol reactivity to the same task (Roubinov et al., 2012). Further, studies document that greater coping flexibility is associated with lower symptoms of depression and anxiety (e.g., Fresco, Williams, & Nugent, 2006). Daily process methods are needed to better capture the range of responses college students report when under stress in their everyday lives. Such methods can be used to examine how these responses might alter cortisol reactivity outside of the lab setting.

Nicolson (1992) conducted one of the only studies involving coping responses and cortisol reactivity using naturalistic assessment. Twenty-eight students provided 10 momentary self-reports and saliva samples each day for 6 days. The college students took a multiple-choice test on the 4^{th} day of the protocol, which represented a typical academic stressor. On average, cortisol levels increased in anticipation of the stressor, but more importantly, problem-oriented (i.e., primary control) coping strategies were associated with lower post-test cortisol levels and distraction and comforting cognition (i.e., secondary control responses) were associated with higher post-test cortisol levels. In other words, primary control coping responses were associated with attenuated cortisol reactivity following the stress of the test, whereas secondary control coping responses were associated with maintained (or even elevated) cortisol levels after the stressor ended. Nicolson's (1992) study still stands as one of the only naturalistic studies to examine coping responses and cortisol reactivity among college students. Given the study's small and homogenous sample and lack of direct replication, additional research is needed to better understand how various coping responses to stress might be related to cortisol reactivity. Although they did not assess cortisol reactivity, Fabes and Eisenberg (1997) measured autonomic regulation (vagal tone) in a lab session and gathered daily stress and coping reports in a sample of college students. Within-person increases in daily stress were associated with greater constructive coping efforts than usual (instrumental coping and support-seeking strategies, excluding emotional venting and drug use) for students with high vagal tone, indicating that highly regulated college students were more likely to cope constructively with perceived daily stress.

Although work using daily process methods is extremely limited in this area, researchers using experimental lab-based studies have identified links between certain coping responses and cortisol reactivity. However, as noted above, the ecological validity of these studies is limited by their assessment of overall or trait-level coping rather than measuring coping responses to a specific stressor (for an exception, see Roubinov et al., 2012). In one study of first-year female college students, problem-focused (i.e., primary control) coping predicted attenuated cortisol reactivity in response to a standardized stress protocol designed to induce anger (Matheson & Anisman, 2009). Rohrmann, Hennig, and Netter (2002) compared salivary cortisol levels among a group of male university students in response to a public speaking task. After completing self-report measures to determine general coping style, those considered "repressors" (who typically avoid stressful situations) exhibited higher cortisol levels in response to giving the speech than "sensitizers" (who typically approach and attend to stressful situations). Roy (2004) examined cortisol levels in response to a speech task among male firefighters (age range: 19-32). A coping strategy characterized by the avoidance of threatening information was associated with larger cortisol increases in response to the stressful lab task. However, results from another more recent study were in direct contradiction to this pattern of findings. Among a community sample of adults, those who more endorsed using avoidant coping strategies more frequently exhibited attenuated cortisol reactivity in response to a lab stressor (Hori et al., 2010).

These inconsistent findings highlight the complexity of studying psychological resources such as coping and their relation to dynamic physiological stress systems. Although the evidence detailed above indicates that efforts to engage with a stressor have most typically been associated with attenuated cortisol reactivity, results are mixed. Other researchers have reported no relation between cortisol and an emotion-focused coping style in college students (Master et al., 2009) or a problem-focused coping style in adults (van Eck et al., 1996b). Disengaged responses have been associated with varied cortisol reactivity patterns across different samples (Denson, Spanovic, & Miller, 2009; Zoccola, Dickerson, & Zaldivar, 2008). These findings from studies utilizing lab-based stress protocols may not translate to more ecologically valid contexts. Research using EMA designs and naturalistic cortisol sampling procedures is needed in order to better capture the complexities of coping with everyday stress in college. Such methods allow for the consideration of temporally proximal responses to naturally occurring stressors, the range of responses individuals use when experiencing stress throughout the day, and ultimately a more complete picture of how college students psychologically and physiologically respond to stress.

The Present Study

The design of the present study draws upon a daily process approach (e.g., Tennen et al., 2000) to examine everyday stress, cortisol reactivity, and self-regulation processes at multiple levels of analysis among adolescents who have entered the college environment. The strengths of this design include repeated moment-to-moment measures of perceived stress, negative affect (NA), and coping responses, within-person comparisons to account for meaningful intra-individual variation in perceived stress and coping responses, and collection of salivary cortisol in the typical daily lives of first-year college students. See Figure 1 for the general conceptual model.

First, I assessed the momentary deviation in perceived stress level from an individual's average perceived stress level across 3 days (15 diary reports) of an EMA protocol. Based on prior findings from earlier waves of this longitudinal study (Doane &

Zeiders, 2014; Drake et al., in press), I also assessed the momentary deviation in NA from an individual's average NA across the 3 days as another momentary indicator of stressful experiences. Second, I modeled naturalistic cortisol reactivity to momentary stress and NA by estimating momentary salivary cortisol levels as deviations from an individual's typical diurnal profile across the 3 days, accounting for waking levels, the cortisol awakening response (CAR), and diurnal slope across the day (e.g., Adam, 2006). Third, I explored within-person differences in the use of voluntary engagement coping responses at the moment and daily level as potential moderators of the within-person associations between momentary stress and NA and cortisol reactivity. Finally, I explored individual differences in various indicators of self-regulatory abilities as person-level moderators of the relations between momentary stress and NA and cortisol reactivity. These included effortful control, ego resiliency, coping efficacy, and relevant composite measures of individual differences in coping from the Brief COPE (Carver, 1997). Based on available literature, the following outcomes were expected:

Hypothesis 1: Within-person increases in momentary perceived stress level and/or NA (i.e., when an individual perceived more stress/NA than was typical for them) would be associated with momentary elevations in cortisol from an individual's diurnal cortisol pattern across the day. This hypothesis was based on prior naturalistic research demonstrating similar associations between stress and/or NA and cortisol levels among adolescents (e.g., Adam, 2006; Doane & Adam, 2010; Doane & Zeiders, 2014).

Hypothesis 2: Engagement coping responses (e.g., planning a solution) measured via momentary diary reports would moderate the association between momentary stress level and cortisol, and/or the association between NA and cortisol. Perceiving more stress or reporting more NA than usual would be associated with momentary elevations in cortisol, unless more momentary engagement coping responses than usual were utilized. This hypothesis was based on prior research using stressful laboratory tasks (e.g., Matheson & Anisman, 2009), as well as limited work in naturalistic settings with college students (e.g., Nicolson, 1992).

Hypothesis 3: Following coping researchers who have argued for the importance of considering the range of responses individuals use to manage stress (e.g., Folkman & Moskowitz, 2004), it was expected that the range of engagement coping responses reported at the end of the day (i.e., using more or less coping categories throughout the day compared to one's typical number of responses) would moderate the momentary associations between stress level and/or NA and cortisol. Due to limited available evidence using daily coping reports in conjunction with saliva sampling, two alternative outcomes were considered. First, perceiving more stress or reporting more NA than usual might have been associated with momentary elevations in cortisol, except for when a greater range of coping responses than usual was utilized that day (possibly reflecting access to greater flexibility to regulate the stress response throughout the day; Roubinov et al., 2012). Alternatively, there might have been momentary within-person associations between stress or NA and cortisol specifically when a greater range of coping than usual was utilized that day (possibly reflecting a more demanding day or failed attempts to regulate the stress response that day).

Hypothesis 4: Given mixed findings concerning the relations between regulatory abilities and cortisol levels in younger children (e.g., Gunnar et al., 2003; Spinrad et al., 2009), it was unclear how individual differences in self-regulation would moderate the associations between stress or NA and cortisol reactivity, particularly when using naturalistic methods among first-year college students in a considerably different developmental context. As such, this research question was exploratory in nature and no specific hypotheses were offered for the moderating role of individual differences in effortful control, ego resiliency, coping efficacy, or trait-level coping.

Method

Participants

A total of 82 adolescents were initially recruited as part of a longitudinal study of the transition from high school into college (e.g., Doane & Thurston, 2014; Doane & Zeiders, 2014; Taylor et al., 2014). They were contacted through orientation activities for the psychology department and email communication at a large southwestern university. Participants were required to live within 35 miles of the university, be a senior in high school at the first assessment (T1), and endorse they planned to attend the university in the fall (T2). Present analyses focus on 71 adolescents (23% male; 17-19 years old; M_{age}

= 18.85, *SD* = 0.54) from the original sample who participated for a third time in the spring semester of their first year of college (T3; 87% retention from T1). Participants were racially and ethnically diverse: 52% Caucasian, 25% Latino/Hispanic descent, 6% African American, 4% Asian American/Pacific Islander, and 13% multiracial. They also came from varying socioeconomic backgrounds as measured by mother's and father's average level of education: 4% of parents completed some high school, 28% had a high school diploma, 25% had some college, 13% received an associate's degree, 17% received a bachelor's degree, and 13% received a graduate degree. Participants lost to attrition from T1 to T3 (n = 11) had parents who completed more education (M = 4.55, SD = 1.44) than parents of participants who remained in the study (M = 3.32, SD = 1.44), $t(80) = -2.58$, $p = .01$. Participants who left the study did not differ significantly on target variables (e.g., effortful control, coping efficacy) or other demographic variables, including sex, race/ethnicity, and whether or not they lived at home during the first semester of college.

One participant did not provide diary data and was not included in analyses. Strict compliance criteria for saliva sampling procedures were taken into account in order to accurately model the diurnal rhythm of cortisol (see details below). In addition to the participant who did not provide diary data, data from 7 participants were excluded for failing to adhere to waking saliva sampling procedures based on objective time indicators (analytic N = 63). Participants excluded for compliance reasons did not differ significantly on demographic variables, including sex, race/ethnicity, average level of parental education, and whether or not they lived at home. They also did not differ significantly on variables of interest (e.g., effortful control, coping).

Procedure

Participants completed a self-report questionnaire including measures of effortful control, ego resiliency, coping efficacy, a coping inventory[2], and health information related to stress physiology (e.g., corticosteroid use) at T1, T2, and T3. Participants selected 3 typical consecutive weekdays to complete a modified EMA protocol (Doane & Zeiders, 2014; Stone & Shiffman, 1994) during the spring semester of their first year of college (T3). For these 3 days participants completed diary reports and provided saliva samples via passive drool 5 times a day: upon waking, 30 minutes after waking, 2 other times during the day (approximately 3 and 8 hours after waking), and at bedtime. In the diary entries participants reported their location; what they were doing, thinking, and feeling; the presence, nature, and severity of any stressful events that had occurred in the last hour; and their responses to these stressful events. Participants also reported sampling time and recent caffeine, nicotine, and medication use. These variables were evaluated as potential covariates given previous research demonstrating associations with HPA axis function. In total, participants were required to fill out 15 diary entries (*M* = 14.74, *SD* = 0.76) and provide 15 saliva samples (*M* = 14.76, *SD* = 0.71), resulting in 1048 momentary data points prior to applying protocol compliance considerations. Diary reports at the end of each day

[2] Only assessed at T3.

included additional questions regarding the use of various engagement coping responses throughout the day (M = 2.89, SD = 0.32, out of 3 total bedtime reports).

Participants were instructed not to eat, drink, or brush their teeth 30 minutes prior to providing a saliva sample. Straws for saliva samples were kept in a MEMS 6™ (Aardex) track cap compliance device, which electronically recorded an objective time stamp when participants opened the container to complete a saliva sample. With necessary precautions taken, researchers have demonstrated adolescents' adherence to the intensive nature of these procedures (Doane & Zeiders, 2014) and similar saliva sampling protocols (Rotenberg & McGrath, 2014). Participants wore the Actiwatch Score (Phillips Respironics, Inc.) on their non-dominant hand, an actigraph wrist-based accelerometer providing an objective measure of wake times. The actigraph also alerted participants when to complete two diary entries along with two saliva samples with auditory alarms at semi-random intervals during the day (approximately 3 and 8 hours after waking). These alarm times were pre-programmed based on participants' estimated wake times to avoid saliva sampling close to mealtimes. Participants also pressed a button on the actigraph when they provided a saliva sample. Both the track cap and the actigraph assessed participants' compliance with saliva sampling procedures (see Doane & Zeiders, 2014).

Noncompliance has been shown to influence cortisol estimates (Kudielka, Broderick, & Kirschbaum, 2003). Track cap data were not available for three participants. However, data from these three participants were included in analyses following careful inspection of cortisol estimates. Saliva samples from remaining participants were considered compliant if waking samples were within 15 minutes of participants' actigraph wake times and second samples were between 23 and 37 minutes after corresponding waking samples (DeSantis, Adam, Mendelsohn, & Doane, 2010). Based on these criteria, data from 7 participants were excluded prior to analyses because there were no compliant waking samples available, which are necessary to model the diurnal rhythm of cortisol (see Appendix for detailed description of these participants' adherence). After excluding all data from these non-compliant individuals, 46 waking samples and 35 second samples from other participants were noncompliant and excluded (analytic $N = 842$ moments).

All materials needed for the study were brought to participants' residences (e.g., dormitories, homes) directly by study personnel, who explained procedures and provided participants with an e-mail address and phone number to reach study personnel at any time. Study personnel then called participants the night before they were scheduled to begin the protocol. After their participation days, study personnel picked up the completed materials and paid participants $75 for completion of the protocol. The university Institutional Review Board approved all procedures. Participants signed consent forms upon delivery of the study materials; parental consents were collected for participants who were under the age of 18.

Measures

Momentary stress level and negative affect. In each diary entry, participants described the most stressful event they encountered in the last hour and how stressful that event was (0 = *not at all stressful* to 3 = *very stressful*). Participants were also asked to rate their negative affect (NA) of the last hour using 10 items from the Positive and

Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988). Example item: "indicate to what extent you have felt distressed in the last hour." Participants responded on a scale from 0 (*very slightly or not at all*) to 4 (*extremely*). Momentary NA scores were formed by averaging scores for ten negative items from each diary entry. Cronbach's alpha values were computed for each momentary report in order to evaluate internal consistency of the 10 items at different times of the day (e.g., 1st entry, 2nd entry, etc.) and ranged from .82 to .88. Stress level and NA were centered within-person across all available diary entries spanning 3 days to represent momentary experiences as deviations from an individual's average level of stress and NA, respectively.

Momentary cortisol reactivity. After study materials were returned to the laboratory, saliva samples were stored at -20C until sent by courier on dry ice over 3 days to Biochemisches Labor at the University of Trier in Germany for assay. Precautions were consistent with recommendations for handling and transporting salivary biomarkers (Granger et al., 2012). Cortisol samples were assayed in duplicate using a solid phase time-resolved fluorescence immunoassay with fluorometric endpoint detection (DELFIA; Dressendörfer, Kirschbaum, Rohde, Stahl, & Strasburger, 1992). The intra-assay coefficients of variation ranged from 4.0% to 6.7% and the inter-assay coefficients of variation ranged from 7.1% to 9.0%. One cortisol outlier value was windsorized at 1.81 µg/dl (equivalent to 50 nmol/L; Nicolson, 2008). Raw cortisol values were natural logarithmically transformed to correct for positive skew. Following Adam's (2006) approach to assess cortisol reactivity in naturalistic settings, day- and person-specific indicators of the diurnal rhythm (CAR and time since waking) were modeled at the moment level. Reactivity was represented as the momentary deviation in cortisol level from an individual's average diurnal pattern of cortisol. See Analytic Strategy below for more detailed explanation of representing cortisol reactivity.

Momentary coping responses. In each diary entry, participants also indicated how much their response to the most stressful event of the last hour included certain coping strategies (0 = *not at all* to 3 = *very*; if momentary perceived stress level was 0 then momentary coping was coded as 0). Items were selected that map on to engagement coping responses from validated self-report questionnaires used with adolescents and college students (Brief COPE: Carver, 1997; RSQ: Connor-Smith et al., 2000). In total, eight items were included with wording modified to specifically capture momentary responses to a recent stressor. Example items include: "doing something to solve the situation" and "distracting myself with thoughts or activities." See Appendix for full list of items.

Exploratory factor analysis (EFA) was conducted to explore potential underlying dimensions of coping in the present sample. Person-level averages of the eight items (i.e., aggregated diary data) were used as measured variables in EFA. Gorsuch (1983) recommends a minimum of five participants per measured variable for EFA. Based on this guideline, the number of participants providing diary data at T3 ($N = 70$) was adequate. Researchers recommend principal axis factoring with direct oblimin (oblique) rotation as the extraction method in EFA utilized for scale construction (e.g., Gorsuch, 1997; Preacher & MacCallum, 2003). Kaiser-Meyer-Olkin's (KMO; Kaiser, 1970, 1974) measure of sampling adequacy indicated these eight items had a high degree of common variance, KMO = .81. Parallel analysis is typically recommended for identifying how many factors to retain for EFA (Kahn, 2006; Zwick & Velicer, 1986). Parallel analysis was conducted using Watkins' (2006) MonteCarlo program, which suggested a one-factor structure. The eigenvalue of the primary factor was 4.53 and the cumulative common variance accounted for was 53%. Therefore, all item scores were averaged to form a composite score reflecting momentary engagement coping responses to a recent stressor. Cronbach's alpha values were computed for each momentary report in order to evaluate internal consistency among the eight items at different times of the day (e.g., 1^{st} entry, 2^{nd} entry, etc.) and ranged from .70 to .78.

Given limited available psychometric work for daily diary data (see Smith et al., 1999; Todd, Tennen, Carney, Armeli, & Affleck, 2004), the eight responses were also carefully evaluated for reliability at the item level. In particular, two of the items that could arguably lack face validity as engagement coping responses were considered: "expressing my feelings to reduce tension" and "giving up trying to deal with it." Although emotional expression has loaded on the higher order factor of voluntary engagement coping in factor analytic work in some samples of adolescents (e.g., Connor-Smith et al., 2000), other developmental research suggests that expressing emotion represents a fundamentally different coping dimension (e.g., Eisenberg et al., 1997). "Giving up trying to deal with it" might reflect avoidance (disengagement) rather than acceptance (engagement), depending on the context and type of stressor. However, removing these items from the devised measure of momentary coping reduced internal consistencies among items at each diary assessment (αs: .62-.74). Thus, the average of eight items reflecting engagement coping responses was treated as the measure of momentary coping to minimize measurement error. Supplementary multilevel analyses were conducted using a six-item version with these two items removed for comparison.

Daily coping responses. At the end of each day, participants responded to 11 additional items adapted from the Responses to Stress Questionnaire (RSQ; Connor-Smith et al., 2000) designed to capture three types of primary control engagement coping responses (problem-solving, emotional expression, emotional regulation) and three types of secondary control engagement coping responses (acceptance, cognitive restructuring, positive thinking). Participants indicated the extent to which they dealt with stress/problems overall throughout the day by using these different coping strategies (0 = *not at all* to 3 = *a lot*). Example items include: "Overall today, how much did you do something to calm yourself down to deal with your problems?" (primary control: emotional regulation) and "Overall today, how much did you tell yourself that things could be worse?" (secondary control: cognitive restructuring). See Appendix for full list of items. Scores on the primary control and secondary control scales from the full version of the RSQ have demonstrated adequate test-retest reliability (.81 and .74, respectively). Previous estimates of internal consistency range from .72 to .84 for items comprising these two types of engagement coping across a range of stressors. In the current sample, Cronbach's alpha values were computed for each day and ranged from .79 to .85.

Following Roubinov et al.'s (2012) approach in a laboratory paradigm, a score for range of daily coping responses was calculated by summing the number of RSQ items that received at least a "1" on the frequency scale for each day. Thus, scores for the range of daily coping responses could range from 0 (no coping endorsed) to 11 (every coping strategy endorsed). Higher values represent using a greater range of strategies directed toward the problem when responding to everyday stress. Although this range score was the primary research focus at the day level, the 11 items were also averaged in the traditional sense to assess the extent to which participants endorsed using engagement coping responses that day.

Effortful control. Participants rated 35 items from the Adult Temperament Questionnaire (ATQ; Evans & Rothbart, 2007) assessing three aspects of effortful control: focusing attention and shifting attention when desired (attentional control; 12 items), suppressing inappropriate behavior (inhibitory control; 11 items), and performing an action when there is a strong tendency to avoid it (activation control; 12 items). Participants rated the extent to which each of the statements described themselves (1 = *extremely untrue of you* to 7 = *extremely true of you*). Example items include: “When interrupted or distracted, I usually can easily shift my attention back to whatever I was doing before” (attentional control), “I can easily resist talking out of turn, even when I'm excited and want to express an idea” (inhibitory control), and “I usually get my responsibilities taken care of as soon as possible” (activation control). Evans and Rothbart (2007) reported Cronbach’s alphas ranging from .65 to .88 for the three factor scales in a sample of college students. Table 1 presents Cronbach’s alpha values for each subscale and bivariate correlations among subscale scores (after reverse scoring the appropriate items). Based on the high degree of interrelatedness among subscale scores at each time point (*r*s ranged from .53-.71 at T1, .59-.65 at T2, and .58-.60 at T3), total scores for effortful control were formed by averaging across all 35 items. Due to the high degree of interrelatedness among total scores across the three time points (*r*s: .70-.82), a composite for effortful control was then formed by averaging across the three assessments.

Ego resiliency. Participants rated 11 items based on a version of Block and Block's (1969, 1980) Q-sort. The shortened 11-item scale was created by Eisenberg et al. (2003) because the original ego-resiliency scale contained items overlapping with other constructs (e.g., emotionality). In order to create the shorter scale, six faculty and five graduate students with relevant expertise rated items from the Block and Block scale for the extent to which they reflected pure resiliency from 1 (*not at all descriptive of resiliency*) to 9 (*most descriptive of resiliency*). Items with a mean score of 6.0 or above (absolute value) were retained. Example items: "I can bounce back or recover after a stressful or bad experience," and "When under stress, I give up and back off." Participants in the current study rated these 11 items from 1 (*most undescriptive of me*) to 9 (*most descriptive of me*). These scores were then averaged after reverse scoring the appropriate items (higher scores reflecting higher ego resiliency). This revised scale (or a highly similar one) has been used reliably in prior studies with children and adolescents (Eisenberg et al., 2003; Taylor, Doane & Eisenberg, 2014; Taylor, Eisenberg, Spinrad, & Widaman, 2013). Cronbach's alphas from T1 to T3 = .64, .77, and .70. See Table 1 for bivariate correlations among scores at each time point. As scores were highly correlated (*r*s: .60-.75), a composite for ego resiliency was formed by averaging across the three assessments.

Coping efficacy. Eight items from the Coping Efficacy Scale (Sandler et al., 2000) were used to measure participants' belief in their ability to use coping strategies to handle stressors and novel situations. Participants responded to items using a 4-point fully anchored scale with unique anchors designed for each item. Example items include: "Overall, how good do you think you will be at making things better when problems come up in the future?" (1 = *not at all good* to 4 = *very good*) and "Overall, compared to other people, how good do you think that you have been in handling your problems?" (1 = *not at all satisfied* to 4 = *very satisfied*). Scores on this measure have demonstrated adequate reliability and validity in samples of children and adolescents (Sandler et al., 2000; Sandler et al., 2003). Scores were summed with higher scores reflecting higher coping efficacy. Cronbach's alphas from T1 to T3 = .85, .91, and .92. See Table 1 for bivariate correlations among scores at each time point. As scores were highly correlated (*r*s: .49-.65), a composite for coping efficacy was formed by averaging across the three assessments.

Coping inventory. Participants completed the Brief COPE (Carver, 1997), a 28-item inventory of 14 typical coping strategies at T3. Compared to the more proximal momentary and daily diary reports, participants were asked to reflect more globally about their typical use of various coping strategies in general to deal with stress "that has to do with getting along with other people" (1 = *I haven't been doing this* to 4 = *I've been doing this a lot*). Example items: "I've been trying to come up with a strategy about what to do" and "I've been getting emotional support from others." Scores on the Brief COPE have demonstrated adequate psychometric properties (Carver, 1997).

Fourteen items representing voluntary engagement coping responses were used as measured variables in EFA to construct meaningful composite scores for individual differences in coping. The 14 items had a high degree of common variance, KMO = .84. Parallel analysis was conducted using Watkins' (2006) MonteCarlo program, which suggested a two-factor structure. After five items loading on divergent third and fourth factors were removed, the pattern matrix revealed that the remaining nine items cleanly loaded on one of the two factors. The eigenvalues of the two factors prior to rotation were 4.58 and 1.58, respectively. The cumulative common variance accounted for was 68%. See Table 2 for rescaled pattern matrix coefficients from the EFA conducted with the nine items. The first factor (five items), called engagement coping, included items related to voluntary engagement coping (i.e., active, planning, cognitive restructuring). The second factor (four items), called support-seeking coping, included items related to soliciting instrumental and emotional support from others. Each of the two factors was treated as a measure of coping, with the mean of items loading on each factor serving as the total score. Cronbach's alphas were strong for engagement coping (.85) and support-seeking coping (.87).

Covariates. Given prior research that has demonstrated associations with salivary cortisol, the following covariates were evaluated as potential person-level controls in multilevel models: sex (1 = male, 0 = female), race/ethnicity (1= non-Hispanic White, 0 = not White), average level of mothers and fathers' education (ranging from 1 = *some high school* to 6 = *graduate school*), oral contraceptive use (1 = currently using a form of oral contraception, 0 = not using oral contraception; all males coded as 0), and grade point average (GPA) from T2 (fall semester of first year of college) obtained from official transcripts provided by the university (Cohen, Doyle, & Baum, 2006; DeSantis et al., 2007; Kirschbaum et al., 1992; Meulenberg, Ross, Swinkels, & Benraad, 1987). Wake time was evaluated as a potential day-level control variable. Reported caffeine and nicotine use in the hour prior to saliva sampling were evaluated as potential moment-level covariates (1 = caffeine/nicotine use in the last hour, 0 = no; Gilbert, Dibb, Plath, & Hiyane, 2000; Lovallo et al., 2005). It is not necessary to control for covariates when they are not expected to explain the relations between independent variables and the outcome, but doing so may reduce error variance in the outcome and increase efficiency in estimation (Sauer, Brookhart, Roy, & VanderWeele, 2013). Only variables significantly associated with cortisol in preliminary analyses or contributing significantly to estimation in multilevel models were included as covariates. Models were also tested with a larger complement of covariates for comparison.

Analytic Strategy

Unconditional multilevel models were estimated using the Mixed Model procedure in SPSS Version 22 to assess cluster-level (between-person) and within-cluster (within-person) variance present for the outcome, independent variables, and potential Level 1 moderator. Intraclass correlations (ICCs)[3] were computed in order to quantify the proportion of cluster-level variance for nested saliva samples and diary reports: $ICC_{cortisol} = .072$, $ICC_{stress} = .199$, $ICC_{NA} = .434$, $ICC_{coping} = .386$. These values represent the degree to which variables violated the independence assumption (1.00 = 100% of variance

[3] ICC = Cluster-level variance/(Cluster-level variance + Residual variance)

accounted for by between-person differences). Although no formal benchmarks are available (West, Ryu, Kwok, & Cham, 2011), these values indicate that the proportion of cluster-level variance present for these nested measures was sufficient to require a multilevel modeling approach in order to avoid Type I error inflation. By considering the residual variances for these variables, moment-to-moment and day-to-day influences accounted for approximately 92.8% of the variance in cortisol, 80.1% of the variance in stress, 56.6% of the variance in NA, and 61.4% of the variance in coping. In sum, the variables assessed via saliva samples and diary reports exhibited sufficient between-person variance to warrant a multilevel modeling approach. However, there was substantial within-person variance (moment-to-moment, day-to-day) across variables of interest, which supports the present research questions.

In an effort to clarify sources of within-person variation prior to multilevel modeling, day-to-day variation in focal independent variables (stress, NA) was explored for specific diary entry occasions (e.g., 1st entry of the day, 2nd entry of the day, etc.). It could have been possible that the degree to which participants' momentary reports of stress and/or NA differed from their typical levels (within-person deviations) depended upon the time of day. For example, it might have been expected that there would be less within-person variation in stress level and NA reported immediately upon waking compared to assessments in the middle of the day when participants were more typically engaged in their environment. However, estimates specific to diary entry occasion indicated that within-person variation in stress level and NA was relatively consistent across the day. For stress level, average within-person *SD*s and the range of these *SD*s were relatively stable: 1^{st} entry *SD* = 0.52, range = 0 – 1.53; 2^{nd} entry *SD* = 0.60, range = 0 – 1.73; 3^{rd} entry *SD* = 0.66, range = 0 – 1.73; 4^{th} entry *SD* = 0.80, range = 0 – 2.12; 5^{th} entry *SD* = 0.72, range = 0 – 1.73. Within-person variation in NA also showed a relatively stable pattern across the day: 1^{st} entry *SD* = 0.20, range = 0 – 1.23; 2^{nd} entry *SD* = 0.20, range = 0 – 1.68; 3^{rd} entry *SD* = 0.19, range = 0 – 0.72; 4^{th} entry *SD* = 0.19, range = 0 – 0.75; 5^{th} entry *SD* = 0.30, range = 0 – 1.97. On average, the 4^{th} entry of the day (approximately 8 hours after waking) and the 5^{th} entry of the day (bedtime) were characterized by the highest within-person variation in stress level and NA, respectively. Given the presence of within-person variation for each diary entry occasion, all available moments of the day were included in analyses.

Day-to-day variation in the range of daily coping was also explored in a similar fashion. The average within-person *SD* was 1.45 (on an 11-point scale) but ranged from 0 to 5.20 across individuals. Fifty-seven percent of the sample had average within-person *SD*s greater than 1.00. Bivariate correlations utilizing the repeated measures data indicated that the range of daily coping tended to be more stable within-person from Day 1 to Day 2 ($r = .60$, $p < .01$) and Day 2 to Day 3 ($r = .74$, $p < .01$) than from Day 1 to Day 3 ($r = .53$, $p < .01$). Although these estimates indicated that there was some day-to-day variation in the range of daily coping, the 3-day protocol is a noted limitation for testing *Hypothesis 3* (see Discussion).

Hierarchical linear growth curve modeling. To account for the nested nature of the data (moments nested within days and persons), three-level hierarchical linear growth curve models were estimated to model momentary-, daily-, and person-level changes in cortisol using HLM Version 6.08 (Raudenbush & Bryk, 2002). Adam's (2006) analytic strategy of using multilevel growth curve modeling to estimate cortisol reactivity in adolescents' naturalistic settings is particularly suited to assess the proposed research questions. This approach adds statistical power by using a within-person, repeated measures design (Raudenbush & Liu, 2001), adjusts for within-person and within-day associations among cortisol levels (Hruschka, Kohrt, & Worthman, 2005), has a relatively high tolerance for missing data, allows for the modeling of multiple cortisol parameters simultaneously (reactivity, waking levels, CAR, diurnal slope), and has the ability to explore both time-varying state (e.g., momentary coping responses) and non-time-varying trait (e.g., effortful control) influences on cortisol reactivity (see also Doane & Adam, 2010; Doane & Zeiders, 2014).

Following this strategy, four sets of models were constructed to test each of the four hypotheses. Models were built up from simple to more complex, with careful attention paid to retaining covariates that accounted for variance in the outcome. For all models, each individual's diurnal cortisol pattern was modeled at Level 1 by including a person- and day-specific time variable (growth parameter) indicating how long after waking the saliva sample was provided that day (0 = wake time) and a dummy variable for the second saliva sample of the day representing the CAR (1 = second sample of the day 30 minutes after waking, 0 = not second sample). A within-person centered indicator of momentary stress level or NA (each tested separately) was included at Level 1 using all available diary entries (i.e., momentary deviations from within-person means of 15 momentary reports). No variables were consistently included at Level 2 across all models, but day-specific wake time and within-person NA (for models testing stress as the IV) were evaluated as potential covariates. At Level 3, person-specific parameters were included to account for between-person differences in waking cortisol levels, the CAR, and diurnal cortisol slope. In addition, random slope testing was conducted in order to investigate whether the associations between Level 1 predictors and the outcome significantly varied across persons. Random slope terms were introduced one at a time. A chi-square likelihood ratio test (nested model test) revealed that the association between time since waking and cortisol levels varied significantly across persons, $\chi^2(2) = 71.46$, $p < .001$. Thus, a random slope term for time since waking was included in all models.

As recommended (Enders & Tofighi, 2007), predictors at Level 1 and Level 2 were centered within-person (i.e., momentary or daily scores subtracted from individual averages of all available scores) and predictors at Level 3 were centered at the grand mean. Exceptions were time since waking (zero reflects day- and person-specific wake time) and dummy variables (CAR, race/ethnicity, etc.). All analyses were conducted using full maximum likelihood estimation with robust standard errors. Models to test Hypotheses 1-4 are detailed below in simplified form using stress as the example focal independent variable. Identical models were tested separately for NA.

Hypothesis 1: Moments of higher stress or NA than usual will be associated with momentary increases in cortisol levels, accounting for an individual's diurnal cortisol pattern. The main effects of within-person stress and NA were tested in separate models.

Level 1 (moment):

momentary cortisol = $\pi_0 + \pi_1$(*CAR*) + π_2(*time since waking*) + π_3(***stress level***) + π_4(*potential moment-level covariates*) + ε

Level 2 (day):

$\pi_0 = \beta_{00} + \beta_{01}$(*potential day-level covariates*) + r_0

$\pi_1 = \beta_{10} + \beta_{11}$(*potential day-level covariates*)

$\pi_2 = \beta_{20} + \beta_{21}$(*potential day-level covariates*)

$\pi_3 = \beta_{30}$

$\pi_4 = \beta_{40}$

Level 3 (person):

$\beta_{00} = \gamma_{000} + \gamma_{001}$(*potential between-person covariates*) + u_{00}

$\beta_{10} = \gamma_{100} + \gamma_{101}$(*potential between-person covariates*)

$\beta_{20} = \gamma_{200} + \gamma_{201}$(*potential between-person covariates*) + u_{20}

$\beta_{30} = \gamma_{300}$

$\beta_{40} = \gamma_{400}$

Hypothesis 2: Perceiving more stress or reporting more NA than usual will be associated with momentary elevations in cortisol, unless more momentary engagement coping responses than usual were utilized. Predictors at Levels 2 and 3 remained consistent with the model detailed above. Within-person centered engagement coping was included at Level 1. Possible interactions were tested separately: stress level x coping and NA x coping,

Level 1 (moment):

momentary cortisol = $\pi_0 + \pi_1$(*CAR*) + π_2(*time since waking*) + π_3(*stress level*) + π_4(***coping***) + π_5(***stress level*coping***) + ε

Hypothesis 3: Using more engagement coping categories than usual throughout the day (within-person increases in the daily range of coping reported at the end of the day) will moderate the momentary associations between stress level and/or NA and cortisol. Level 3 predictors remained consistent.

Level 1 (moment):

$\textit{momentary cortisol} = \pi_0 + \pi_1(\textit{CAR}) + \pi_2(\textit{time since waking}) + \pi_3(\textit{stress level}) + \varepsilon$

Level 2 (day):

$\pi_0 = \beta_{00} + \beta_{01}(\textbf{\textit{daily range of coping}}) + r_0$

$\pi_1 = \beta_{10}$

$\pi_2 = \beta_{20}$

$\pi_3 = \beta_{30} + \beta_{31}(\textbf{\textit{daily range of coping}})$

Hypothesis 4: Exploring whether individual differences in effortful control, ego resiliency, coping efficacy, and composite measures of coping moderate the momentary associations between stress and NA and cortisol levels. Level 1 and Level 2 predictors remained consistent with the original model. Potential moderators were tested separately. Effortful control is used below as an example.

Level 3 (person):

$\beta_{00} = \gamma_{000} + \gamma_{001}(\textit{potential between-person covariates}) + \gamma_{002}(\textbf{\textit{effortful control}}) + u_{00}$

$\beta_{10} = \gamma_{100} + \gamma_{101}(\textit{potential between-person covariates})$

$\beta_{20} = \gamma_{200} + \gamma_{201}(\textit{potential between-person covariates}) + u_{20}$

$\beta_{30} = \gamma_{300} + \gamma_{301}(\textbf{\textit{effortful control}})$

Significant two-way interactions were investigated using the simple slopes technique for hierarchical linear modeling outlined by Preacher, Curran, and Bauer (2006). Simple slopes were estimated for associations between momentary stress or NA and cortisol at differing levels of self-regulation/coping (at the mean and 1 *SD* above and below the mean; Aiken & West, 1991). The range of self-regulation or coping for which the moment-level relations were statistically significant was also assessed.

Results

Descriptive Statistics and Zero-Order Correlations

Table 3 presents descriptive statistics and zero-order correlations among diurnal cortisol, stress level, NA, coping, measures of self-regulation, and covariates. Nested data were aggregated for descriptive purposes only. Average waking levels of cortisol were significantly negatively associated with average cortisol awakening responses (CARs), $r(61) = -.68$, $p < .01$. Average parental education level was significantly correlated with higher average CARs ($r = .28$, $p = .03$) and steeper diurnal cortisol slopes ($r = -.27$, $p = .03$). On average, non-Hispanic White participants exhibited significantly steeper diurnal cortisol slopes than their non-White peers ($r = -.40$, $p < .01$).

Average stress level and NA were moderately positively correlated ($r = .34$, $p < .01$). Consistent with classic stress-coping theory, average stress level was positively correlated with momentary engagement coping ($r = .54$, $p < .01$). Average NA was also positively correlated with engagement coping ($r = .56$, $p < .01$). Average daily range of coping was not significantly correlated with average stress level ($r = .16$, $p > .05$) but was positively correlated with average NA ($r = .40$, $p < .01$) and average momentary engagement coping ($r = .46$, $p < .01$).

As expected, effortful control, ego resiliency, and coping efficacy were highly positively correlated (*r*s: .57-.69, *p*s < .01). The newly formed engagement coping composite was moderately correlated with effortful control, ego resiliency, and coping efficacy (*r*s: .43-.49, *p*s < .01), while the support-seeking coping composite was only correlated with coping efficacy ($r = .30$, $p = .02$) and engagement coping ($r = .41$, $p < .01$). Support-seeking coping was also positively correlated with average NA ($r = .24$, $p = .05$).

Hypothesis 1: Within-Person Increases in Stress and NA Predicting Cortisol Reactivity

Participants exhibited the expected diurnal cortisol profile with relatively high waking levels ($\gamma_{000} = -1.42$, $p < .001$; equivalent to 0.24 μg/dl or 6.69 nmol/L), an approximate 75% increase 30 minutes after waking (the cortisol awakening response, CAR; $\gamma_{100} = 0.56$, $p < .001$),[4] and an approximate 12% decline in cortisol per hour at waking ($\gamma_{200} = -0.11$, $p < .001$), after allowing the slope of time since waking to vary randomly across persons (Table 4, Model 1). Between-person differences in race/ethnicity (White = 1, non-White = 0) accounted for significant variance in the intercept (average waking cortisol levels) and the diurnal cortisol slope, between-person differences in oral contraceptive use (Yes = 1, No = 0, all males = 0) accounted for significant variance in the intercept and CAR, and average parental education level

[4] Because cortisol values were log transformed, the effect sizes can be interpreted as a percent change per 1 unit change in the predictor after using the formula: β% change = [(e^β) – 1].

accounted for significance variance in the intercept, CAR, and diurnal slope; thus, these between-person covariates were included in all subsequent models (Table 4, Model 2). Accounting for the diurnal pattern of cortisol and these covariates, within-person momentary stress level was not significantly associated with momentary deviations in cortisol (γ_{300} = 0.03, p = .22; Table 4, Model 2). Within-person increases in momentary NA were significantly associated with momentary increases in cortisol relative to the diurnal rhythm (γ_{300} = 0.06, p = .03; Table 4, Model 3). When individuals reported NA 1 *SD* above their own average level of NA across all diary entries, they exhibited a corresponding 6% increase in cortisol levels.

Hypothesis 2: Moment-Level Coping

Within-person centered momentary engagement coping was entered as a main effect term at Level 1.[5] In addition, the product of within-person centered momentary stress level and within-person centered momentary engagement coping was entered at Level 1 (Table 5, Model 1). Adjusting for momentary stress level, within-person increases in momentary engagement coping were significantly associated with momentary decreases in cortisol relative to the diurnal rhythm (γ_{400} = -0.07, p = .05). The interaction between momentary stress level and coping was also significant (γ_{500} = 0.07, p = .02). Following similar analytic steps in a separate model, the interaction between momentary NA and coping was not significant (γ_{500} = 0.01, p > .50; Table 5, Model 2).

Probing the stress x coping interaction revealed that within-person increases in momentary stress level were associated with increases in cortisol during moments when

[5] Using eight items as described in the measures section. Models were also tested with a six-item version and the pattern of findings did not differ.

individuals endorsed coping 1 *SD* above their own mean (β = 0.13, $p < .001$) or at their mean (β = 0.06, $p = .06$) but not at 1 *SD* below their mean (β = -0.003, *ns*; Figure 2). The within-person association between stress and cortisol was statistically significant only for moments when individuals scored at least 0.04 *SD* above their mean of coping (42% of all moments in the sample).

Hypothesis 3: Day-Level Coping

Within-person centered daily range of engagement coping responses was entered on the intercept at Level 2 (i.e., association with average waking levels of cortisol). Daily range of coping was also entered as a cross-level interaction term separately for the associations between momentary stress level and momentary NA and cortisol (Models 1 and 2, Table 6). Within-person changes in the range of daily coping responses did not significantly account for average waking levels of cortisol (main effect; $p > .50$) and neither of these interactions were significant (*p*s > .20). In addition, within-person changes in engagement coping (based on the average of 11 daily diary items, rather than the sum of the number of endorsed items) did not significantly account for average waking levels of cortisol (main effect; $p > .75$). There were also no significant interactions with momentary stress level or NA (*p*s > .60).

Hypothesis 4: Person-Level Self-Regulation and Coping

At Level 3, self-regulation/coping variables (effortful control, ego resiliency, coping efficacy, engagement coping, support-seeking coping) were entered separately on the intercept and as cross-level interaction terms for the associations between momentary stress level or NA and cortisol (Table 7). Neither effortful control nor ego resiliency significantly moderated the within-person association between momentary stress level and cortisol (Table 7, Models 1 and 2). However, a significant cross-level interaction emerged between within-person momentary stress (Level 1) and coping efficacy (Level 3; $\gamma_{301} = -0.05$, $p = .02$; Model 3). Similarly, engagement coping significantly moderated the within-person association between momentary stress level and cortisol ($\gamma_{301} = -0.06$, $p = .02$; Model 4).

Probing the stress x coping efficacy interaction revealed that the positive within-person association between momentary stress level and cortisol was significant only for those scoring 1 *SD* below the mean ($\beta = 0.08$, $p = .01$) but not at the mean ($\beta = 0.03$, $p = .17$) or 1 *SD* above the mean ($\beta = -0.02$, *ns*) of coping efficacy (Figure 3). The positive association between stress level and cortisol was statistically significant only for those scoring 24.00 (0.32 *SD* below the mean) or lower on the Coping Efficacy Scale (35% of the sample). Similarly, probing the stress x engagement coping interaction revealed that the positive association between stress level and cortisol was significant only for those scoring 1 *SD* below the mean ($\beta = 0.09$, $p < .01$) but not at the mean ($\beta = 0.03$, $p = .17$) or 1 *SD* above the mean ($\beta = -0.03$, *ns*) of engagement coping (Figure 4). The positive association between stress level and cortisol was significant only for those scoring 2.60 (0.23 *SD* below the mean) or lower on the composite measure of engagement coping (44% of the sample).

Finally, a significant cross-level interaction also emerged between within-person momentary NA and support-seeking coping ($\gamma_{301} = -0.07$, $p < .01$; Table 7, Model 5). Probing the interaction revealed that the positive association between momentary NA and cortisol was significant for those scoring 1 *SD* below the mean ($\beta = 0.13$, $p < .01$) and at the mean ($\beta = 0.06$, $p = .03$) but not 1 *SD* above the mean ($\beta = -0.01$, *ns*) of support-seeking coping (Figure 5). The positive association between NA and cortisol levels was significant for those scoring 2.50 (0.08 *SD* above the mean) or lower on the composite measure of support-seeking coping (62% of the sample).

Additional Analytic Considerations

Given the research questions and theoretical orientation of the project (Tennen et al., 2000), within-person associations were emphasized in these analyses. This decision to center Level 1 predictors within person (within-cluster centering) given the research focus follows multilevel modeling recommendations (Enders & Tofighi, 2007). Between-person differences in momentary and daily coping were also explored as moderators in preliminary fashion (i.e., centered at the grand mean). In summary, deviations in momentary or daily coping from the overall sample average were not significant moderators of the within-person associations between momentary stress level or NA and cortisol. This suggests that the within-person associations between stress, NA, and cortisol do not vary depending on between-person differences assessed using diary reports across 3 days.

The presented patterns of results were consistent when accounting for additional covariates: time since waking^2 (potential curvilinear effect), caffeine and nicotine use at Level 1, wake time at Level 2, and sex and T2 GPA at Level 3. Results were also consistent without controlling for parental education level at Level 3. Models examining the effect of stress level were consistent when controlling for within-person NA at Level

2 (day-to-day variation in NA). Models testing *Hypothesis 3* (daily coping) were consistent when adjusting for between-person differences in coping. Simplified model results were presented because these additional potential covariates did not substantially contribute to prediction of cortisol and results were consistent without these covariates.

Additional Saliva Sampling Compliance Considerations

Due to the critical nature of participant adherence to saliva sampling protocols in naturalistic settings (Kudielka et al., 2003; Rotenberg & McGrath, 2014), comparison analyses were conducted to examine whether excluding participants' data based on compliance concerns influenced model estimates (Table 8). Three samples of participants were considered: all participants who adequately provided data ($N = 70$), excluding participants and specific saliva samples deemed not compliant ($N = 63$, the results presented here), and excluding these participants and specific saliva samples as well as three participants for whom no compliance information was available (i.e., did not use the track cap; $N = 60$). The significant interaction between moment-level stress and moment-level coping ($N = 63$) was at a trend level with the complete sample ($p = .12$; $N = 70$). The significant cross-level interactions for engagement and support-seeking coping ($N = 63$) were only marginally significant with the complete sample ($N = 70$). However, the primary pattern of findings presented here generally did not differ across these three analytic samples, suggesting the results are relatively robust to violations of compliance to the saliva sampling protocol.

Discussion

The developmental transition between adolescence and full-fledged adulthood is a period characterized by pervasive and simultaneous changes in context, daily demands, and social roles (Arnett, 2000; Schulenberg et al., 2004; Steinberg et al., 2004). In the U.S., many adolescents enter the college environment during this time (U.S. Bureau of Labor Statistics, 2013). First-year college students face novel daily stressors that have been linked to poor physical and psychological health (e.g., Compas et al., 1986; Wagner et al., 1988), while continuing to develop capacities for self-regulation (Pennebaker et al., 1990; Steinhardt & Dolbier, 2008). The HPA axis, one of the body's primary stress response systems, allows individuals to recruit resources in order to manage the demands of everyday stress and negative emotions (Adam, 2012; Gunnar & Quevado, 2007). Adolescents also utilize cognitive and behavioral coping strategies with varying success during the college years to promote adaptation to everyday stress (Fabes & Eisenberg, 1997; Nicolson, 1992).

Guided by biopsychosocial (Bernard & Krupat, 1994) and daily process (Tennen et al., 2000) frameworks, this thesis expanded upon available literature by examining moment-to-moment and day-to-day variation in engagement coping responses to everyday stress using a modified 3-day EMA protocol (Stone & Shiffman, 1994). This approach was employed in combination with naturalistic salivary assessment in order to model momentary deviations in cortisol from individual diurnal patterns concurrently with momentary diary reports of perceived stress and NA (i.e., naturalistic momentary cortisol reactivity; Adam, 2006; Doane & Zeiders, 2014). Individual differences in various indices of self-regulation (e.g., effortful control, coping efficacy, engagement coping) were also assessed in an effort to compare the moderating roles of dynamic processes and more stable features of self-regulation within the same study. Results from hierarchical linear growth models replicated a consistent finding across adolescent samples (Adam, 2006; Doane & Zeiders, 2014): within-person increases in NA were significantly associated with momentary increases in cortisol relative to an individual's diurnal rhythm. Additionally, within-person increases in perceived stress level were significantly associated with increases in cortisol only during moments when individuals used more engagement coping responses than usual. Day-to-day changes in the range of reported engagement coping responses did not significantly moderate within-person associations between stress level or NA and cortisol. Although individual differences in effortful control and ego resiliency did not significantly moderate these moment-to-moment associations, there were significant interactions for coping efficacy, engagement coping, and support-seeking coping. Interpretations of these results are detailed below.

Hypothesis 1: Everyday Stress, Negative Affect, and Momentary Deviations in Cortisol

Consistent with the hypothesis, adolescents in their first year of college exhibited momentary increases in cortisol (accounting for their individual diurnal cortisol pattern) when they reported more NA in the last hour than their typical average. This finding is consistent with laboratory evidence that has demonstrated cortisol reactivity to uncontrollable, socially-evaluative stressors that commonly elicit NA (Dickerson & Kemeny, 2004). This finding is also consistent with research in naturalistic settings that has found momentary elevations in cortisol in relation to more worry/stress than usual among 13-17 year olds (Adam, 2006), more loneliness than usual among 17-20 year olds (Doane & Adam, 2010), and more NA than usual among adolescents of the present study at earlier assessments (Doane & Zeiders, 2014; Drake et al., in press). Similar findings have also been reported using slightly different methods among adults (Jacobs et al., 2007). Replicating this pattern of findings outside of the laboratory suggests that the positive relation between momentary NA and cortisol is particularly robust. Cortisol levels peak approximately 20-25 minutes following a stressor (Adam, 2012; Nicolson, 2008). As such, approximating changes in cortisol using this naturalistic approach is likely an underestimation of true cortisol "reactivity."

It was also expected that within-person increases in perceived stress level would be associated with momentary elevations in cortisol, which was not supported in the present analyses. Perceptions (i.e., appraisals) of stress have been theoretically linked with subsequent physiological reactivity in contemporary stress process models (Cohen et al., 1995; Miller et al., 2011). However, the empirical evidence is somewhat less consistent for perceived stress (which could be negatively or positively valenced) eliciting the cortisol response, compared to specifically negative stimuli (Dickerson & Kemeny, 2004). Past research has found that stressful daily events were associated with increased cortisol in adults' daily lives, with tentative evidence that NA mediated the association between stress and cortisol (Smyth et al., 1998; van Eck et al., 1996b). Although mediation was not formally tested in the present analyses, the results do suggest that the direct link between NA and the cortisol response is more pronounced than the link between perceived stress and cortisol. This could be due to several reasons: the most stressful events of the last hour could have included both positive and negative components, they could have been controllable, or their effect on cortisol could have depended on the type of perceived stressor (e.g., academic, social). It would be interesting for future research in real-world contexts to consider specifically social and/or negatively-valenced perceived stressors in an effort to better reflect the known psychological reagents of the HPA axis response in the lab.

Researchers have disagreed on the health implications of relative elevations in cortisol and whether they should be considered "adaptive" or "maladaptive." Some models of stress reactivity assume that heightened or extreme responses are harmful while smaller responses are beneficial (Lovallo, 2005; Lovallo & Gerin, 2003). Others suggest that both exaggerated and blunted stress reactivity indicate dysregulation with negative implications for health (Lovallo, 2011). This thesis avoids attaching value labels to momentary elevations in cortisol, mainly because higher cortisol than expected in a given moment was expected to depend on variation in one's capacities to manage stressful and emotional daily demands. Recent models have adopted the perspective that elevated cortisol levels have advantages and disadvantages for adaptation that must be understood across contexts as well as between individuals (Shirtcliff, Peres, Dismukes, Lee, & Phan, 2014). This recent view exemplifies precisely why the proper measurement of stressful circumstances and physiological responses in ecologically valid settings is so important. Although EMA protocols lack the experimental control and (as of yet) the standardization of the lab, these methods allow for the examination of naturally occurring stress processes that vary within and between individuals (Tennen et al., 2000). The present study does not offer direct evaluation of how more NA than usual may lead to health outcomes through deviations in cortisol. However, it does advance a contextually-based approach to investigate the everyday stressful and emotional experiences that first-year college students truly face during a dynamic social and developmental transition.

Hypothesis 2: Momentary Coping

The relation between momentary perceived stress and cortisol must be interpreted within the context of momentary coping efforts. Momentary engagement coping responses significantly moderated the within-person association between stress and cortisol, but the hypothesized pattern of this interaction was not supported. Rather than suggesting that coping responses to a recent stressor buffer first-year college students from elevated HPA axis activation, the results indicated that perceiving greater stress than usual was significantly associated with higher cortisol compared to moments of average or lower stress only when individuals reported using *more* engagement coping than usual. This interactive effect does not align with laboratory studies that have demonstrated how general tendencies of coping actively (i.e., trait coping) contribute to attenuated HPA axis responses (e.g., Matheson & Anisman, 2009; Rohrmann et al., 2002). However, measuring coping responses to recent naturally occurring stressors in the present study allowed for more careful consideration of how coping modulates physiological reactivity in the real world. Importantly, (in the same model) more momentary engagement coping than usual was associated with significantly lower cortisol levels, after accounting for the diurnal rhythm and perceived stress level (conditional main effect). In other words, using more engagement coping than usual was associated with lower momentary cortisol than what would be expected based on an individual's diurnal pattern, but with higher momentary cortisol when first-year college students perceived more stress compared to average or less stress than usual.

There are several potential explanations for this interaction between stress and coping at the moment level. Theory suggests that the psychological experience of stress occurs when perceived demands from the environment exceed an individual's ability to cope with them (Folkman & Lazarus, 1984). In this case, moments characterized by more engagement responses than usual could represent particularly demanding situations that required the use of more active coping efforts. Indeed, previous research has demonstrated that *how* one copes with stress may more readily predict positive adaptation, whereas *how much* one copes may actually reflect one's level of distress (Forsythe & Compas, 1987). Momentary reports characterized by more coping and higher perceived stress than usual might represent situations in daily life that were actually more demanding, which contributed to relatively higher cortisol levels compared to moments characterized by the same degree of coping and lower perceived stress. Alternatively, engaging with recent stressors by actively coping might have contributed to HPA axis activation that was necessary to recruit physiological and psychological resources. This interpretation is consistent with models emphasizing the adaptive nature of changes in cortisol (Shirtcliff et al., 2014). Finally, it might be less likely given the retrospective nature of the diary reports, but it is also possible that momentary elevations in cortisol facilitated the use of greater engagement coping following situations perceived as more stressful than usual (rather than the direction presented here). Although cortisol is the end product of the HPA axis stress response, the hormone also serves a regulatory function via negative feedback mechanisms that suppress autonomic nervous system activity (Sapolsky, Romero, & Munck, 2000). In sum, probing the significant interaction between stress and coping revealed a pattern that was contrary to expectations. The finding supports that the cortisol response to stress depends upon momentary within-person fluctuations in engagement coping.

Of note, momentary engagement coping did not significantly moderate the within-person association between NA and cortisol. Average perceived stress and NA were positively correlated but only momentary NA was directly associated with elevations in cortisol, suggesting that these two measures captured related but different components of everyday stressful experiences. The measure of NA comprised 10 negatively-valenced mood states (e.g., irritable, ashamed, afraid), which likely captured more contextual nuance about one's experiences from the previous hour compared to the single item for perceived stress level. Given that negatively-valenced stressors are most consistently linked to cortisol reactivity (Dickerson & Kemeny, 2004), the coping responses that were measured might not have been sufficient to modulate the robust cortisol response to NA. Different types of coping that were not assessed in the diary reports, such as emotion-focused or support-seeking, might be more effective tools to regulate emotional reactivity. Developmental timing must also be considered. It could be that first-year college students have successfully learned coping skills to manage situations they perceive as stressful but still react to NA regardless of active coping efforts. Future research should continue exploring the utility of daily diary reports to assess natural variation in coping responses by including other dimensions and typologies in addition to engagement coping.

Hypothesis 3: Daily Coping

Day-to-day differences in the range of engagement coping did not significantly moderate the momentary associations between stress or NA and cortisol. In other words, momentary associations between stress or NA and cortisol were not significantly different on days when first-year college students used more varieties of engagement coping. This was consistent after adjusting for between-person differences in engagement coping. Methodological limitations could have influenced the lack of significant findings at the day level. At maximum, only three end-of-day diary reports were available for each college student in order to form within-person averages (compared to up to 15 momentary diary reports for stress, NA, and coping). Days characterized by extremely low or high ranges of coping could have greatly influenced individual averages and thus within-person variation from these averages. Although other research has successfully examined day-to-day variation in stress and social experiences in relation to biological measurements using 3-day protocols (e.g., Doane & Thurston, 2014; Sladek & Doane, 2015), more repeated daily assessments would be preferable to adequately test the moderating role of day-to-day variation in coping. The present study was limited by the number of assessment days in favor of gathering more detailed momentary diary entries and collecting saliva. The continued integration and refinement of these methods will be necessary in order to better understand how stress and coping processes fluctuate within adolescents navigating their first year of college.

Two possible *a priori* hypotheses were considered for this interaction given limited prior evidence using similar methods to assess daily coping and cortisol. Perceiving more stress or reporting more NA than usual was expected to be associated with momentary elevations in cortisol *except* or, conversely, *only* on days when individuals utilized a greater range of coping than usual. Coping flexibility, which increases with development (Losoya et al., 1998), has been associated with psychological well-being (Fresco et al., 2006) and with attenuated cortisol reactivity to a lab stress task (Roubinov et al., 2012). Using a greater range of engagement coping responses throughout the day could reflect access to a greater number of potentially useful regulation strategies. On the other hand, using a greater range of coping responses could also indicate a more demanding day or failed attempts to regulate reactions to stress (i.e., moving on to other coping efforts when one does not work). Using more types of engagement coping on a given day could have represented different daily experiences for different first-year college students – days of flexible, effective coping for some vs. days of demanding, heightened stress for others. The type and controllability of everyday challenges also might have influenced whether a greater range of engagement coping on a particular day contributed to regulatory processes. For example, using a wider range of coping strategies directed towards the source of social and uncontrollable stress (e.g., discrimination, prejudice) might reflect perseverating over situations outside of one's control, whereas a wider range of engagement coping in response to academic and controllable stress (e.g., studying for exams) might reflect successful regulation.

Hypothesis 4: Individual Differences in Self-Regulation and Coping

Effortful control and ego resiliency. Individual differences in effortful control and ego resiliency (highly correlated in this sample) did not significantly moderate the within-person associations between stress or NA and cortisol. These potential cross-level interactions (individual differences in self-regulation explaining variance in the momentary associations between stress/NA and cortisol) were exploratory in nature. Only a handful of studies have examined between-person differences as moderators of the cortisol response in adolescents' naturalistic settings (Adam, 2006; Doane & Adam, 2010; Doane & Zeiders, 2014) and even fewer have done so among adolescents in the college environment. Effortful control and ego resiliency generally predict positive adjustment in college (Srivastava et al., 2009; Taylor et al., 2014). Effortful control has been associated with both higher and lower cortisol reactivity (Gunnar et al., 1997; Spinrad et al., 2009) and ego resiliency with lower cortisol reactivity among preschoolers (Smeekens et al., 2007). However, the methods, modeling techniques, and developmental period of this thesis differ substantially from those in extant literature involving effortful control and ego resiliency.

It is possible that these indicators of self-regulation may play a more substantial role in modulating stress reactivity earlier in life as children develop capacities for self-regulation and coping skills. Individual differences in effortful control or ego resiliency may play a moderating role in the link between more chronic stress or the culmination of life adversity and changes in cortisol activity across a longer time course, rather than for the relatively minor challenges captured in the present daily process design. Given the exploratory nature of this research question using a longitudinal sample of adolescents transitioning to college, these potential explanations are merely conjecture. Future research might consider how early differences in self-regulation contribute to the development of coping skills over time, which in turn serve to regulate cortisol responses to everyday stressors.

Coping efficacy. The within-person association between momentary perceived stress level and cortisol was significantly moderated by individual differences in coping efficacy. Although there was not a significant main effect of momentary stress on changes in cortisol overall, first-year college students below average on coping efficacy exhibited significantly higher cortisol during moments when they perceived greater stress compared to moments of average or less stress than usual. Those average or above average on coping efficacy did not exhibit momentary elevations in cortisol when perceiving more stress than usual. Coping efficacy did not moderate the momentary association between NA and cortisol.

The moderating effect of coping efficacy can be better understood from the perspective of the secondary stress appraisal process, during which individuals evaluate whether they can manage stressful demands in order to adapt to potential threats (Lazarus & Folkman, 1984). Those who have greater confidence in their ability to handle stress (higher coping efficacy) would be expected to benefit from enhanced self-regulation. Researchers have commonly examined coping efficacy as a mediator of the relation between coping skills and adjustment (e.g., Prelow et al., 2006; Sandler et al., 2000). Fewer have explored coping efficacy as a moderator of cortisol reactivity, but the finding in this thesis is conceptually similar to the results of a recent study using data from earlier assessments of this sample. In this recent study, coping efficacy significantly moderated the association between longitudinal changes in loneliness across the college transition and diurnal cortisol regulation in the college environment (Drake et al., in press). Although this thesis is focused on momentary deviations in cortisol rather than diurnal regulation, both sets of findings suggest that greater belief in one's ability to handle the demands of stressful situations contributes to regulation of HPA axis activity in the real-world settings of adolescents as they transition to college. Coping efficacy appears to be a developmentally appropriate indicator of the extent to which adolescents have established the capacity to handle everyday stress. This interaction exemplifies the dynamic transactions between stress and coping processes that together afford better estimation of physiological reactivity and promote adaptation (Bernard & Krupat, 1994; Folkman & Lazarus, 1984).

Engagement coping. The within-person association between momentary perceived stress and cortisol was significantly moderated by individual differences in engagement coping (e.g., problem-solving, taking action). For those scoring above average on engagement coping, momentary cortisol did not vary as a function of within-person changes in momentary stress. For those scoring at or below average on engagement coping, within-person increases in momentary perceived stress were positively associated with cortisol. Unlike the cross-level interaction for coping efficacy, however, individual differences in engagement coping explained significant variation in cortisol during moments of less perceived stress rather than moments of greater stress. Those below average on engagement coping exhibited significantly lower momentary cortisol during moments of lower perceived stress than usual, compared to those higher on engagement coping (see Figure 4). The association between momentary NA and cortisol was not significantly moderated by engagement coping, suggesting again that perceived stress and NA represent different components of everyday stressful experiences, the effects of which are modified by different regulation processes.

Actively engaging through coping efforts directed toward the source of stress has typically been associated with more positive psychological adjustment during adolescence (Compas et al., 2001; Connor-Smith et al., 2000). In past research among college students, active coping has been associated with attenuated cortisol reactivity to a stressful lab task (Matheson & Anisman, 2009) and lower cortisol levels following a real-world exam (Nicolson, 1992). The significant interaction in the present study complements this past work by demonstrating that first-year college students who typically use more engagement coping strategies did not exhibit significantly higher momentary cortisol when perceiving unusually high levels compared to lower levels of everyday stress. Only students who typically use less engagement coping exhibited significantly higher momentary cortisol when perceiving more stress than usual in their everyday life. Those who more typically direct attention toward the source of the problem when faced with stressful situations (e.g., problem-solving, planning, taking action) may have developed a more successful pattern of responding to these routine daily stressors over time, and are thus better equipped to regulate moment-to-moment changes in cortisol. Of course, these first-year college students who were higher on engagement coping also exhibited significantly higher cortisol during moments of less stress than usual, compared to their peers who were average or below average on engagement coping. An additional explanation could be that these high engagement students are generally more socially competent and more open to social experiences than their peers who less routinely engage with stressful experiences in their environment; thus, the students who more readily engage with their environment might exhibit relatively higher HPA activity compared to their less engaged peers, even when daily events are not perceived as particularly stressful. This interpretation is consistent with some research demonstrating that socially competent children exhibit higher cortisol than their less competent peers in a variety of contexts (e.g., Gunnar et al., 1997).

Important to note, both within-person (moment to moment) and between-person differences in engagement coping were significant moderators in the present analyses, yet the pattern of these two interactions were actually opposite one another. When individuals used greater engagement coping in response to a stressful situation, the perceived level of stress was associated with higher cortisol; when trait levels of engagement coping were above average, however, perceived stress was *not* associated with higher cortisol. These differential findings underscore the importance of multiple levels of analysis in the study of coping, particularly because measures of trait coping or coping style do not necessarily predict individuals' actual coping strategies in real life (Ptacek et al., 1994; Schwartz et al., 1999; Smith et al., 1999). The findings further highlight within-person (state) and between-person (trait) differences in regulation processes that should be considered in coping research. This thesis contributes methodologically and substantively to stress, coping, and cortisol research by incorporating both diary reports and more standard self-report questionnaires in the same study.

Support-seeking coping. Individual differences in support-seeking coping (i.e., tendency to seek help or emotional support from others) did not significantly moderate the momentary within-person association between stress and cortisol, but did significantly moderate the association between NA and cortisol. Cortisol was significantly higher during moments characterized by higher NA than moments of average or lower NA than usual only for individuals low and average on support-seeking coping. For those above average on support-seeking coping, cortisol was not significantly different during moments of more NA than moments of less NA than usual.

Similarly, a recent study examining the present sample when adolescents were still in high school found that those reporting higher perceived social support from friends did not exhibit significant elevations in cortisol during moments when they reported higher NA than usual (Doane & Zeiders, 2014). The stress buffering hypothesis (Cohen & Wills, 1985) and its supporting empirical evidence in stress physiology research (e.g., Lee, Suchday, & Wylie-Rosett, 2012; Uchino & Garvey, 1997) suggest that perceived availability of social resources protects individuals from the potentially adverse effects of stressful events. Those high on support-seeking coping in the present study may have been those with more established social support systems that allow them to more effectively manage fluctuating negative emotions. Support-seeking coping has been distinguished from other coping dimensions in developmental research (e.g., Ayers, Sandler, West, & Roosa, 1996). This thesis identifies support-seeking coping as a moderator of the cortisol response to NA in the daily lives of first-year college students during a period of development characterized by highly variable emotions (Neupert et al., 2007). Support-seeking or other social coping efforts may serve as valuable targets for intervention or prevention programs aimed at improving regulation strategies among adolescents transitioning to the college environment. It is intriguing to consider whether regulation based in social processes differs in physiological function compared to regulation based in one's own abilities (e.g., coping efficacy), particularly among adolescents undergoing the major social shift of transitioning to college. Based on the findings presented here, patterns of coping that involve others may be more suited for regulating the cortisol response to NA, whereas patterns based in self-regulation may be better suited for regulating the cortisol response to perceptions of everyday stress.

Limitations

This sample of first-year college students drawn from a longitudinal study of the transition from high school to college was modest in size, disproportionately female, and lived exclusively within a 35 mile radius of the university during high school. For research examining between-person differences, a sample size of 71 (63 after excluding non-compliant individuals) appears small. However, the study was designed with a keen focus on within-person processes (intensive repeated assessments of both psychosocial and biological measures) and was thus well-equipped to test the proposed research questions. Simulation multilevel modeling studies have indicated that only sample sizes of 50 or less at the highest level (e.g., person level) typically lead to biased estimates of standard errors; sample sizes greater than 50 (as in the present study) typically result in unbiased and accurate estimates of the regression coefficients, variance components, and standard errors (Maas & Hox, 2005). If possible, future studies should adopt similar intensive protocols with larger samples sizes. With respect to the greater number of female participants, research has demonstrated sex differences in perceptions of stress, coping, and HPA axis activation during adolescence and adulthood (e.g., Dyson & Renk, 2006; Hampel & Petermann, 2006; Kirschbaum et al., 1992; Tamres, Janicki, & Helgeson, 2002). Unfortunately it was not possible to systematically test whether associations differed by sex in the present analyses given the low number of males in the sample. Due to constraints of the protocol (e.g., delivering and picking up materials in person), participation in the longitudinal study was exclusive to high school students from the local area. Thus, the present results may not generalize to students moving farther away from home for school, whose transition to college experience likely differs. In addition, participants were not asked to report whether or not they were working a job while being a full-time student, a lifestyle characteristic that warrants future research focused on everyday stress in this age group.

Although there is a wealth of research using paper-and-pencil diary reports with adolescents and college students comparable to the present study (e.g., Adam, 2006; Doane & Adam, 2010; Fabes & Eisenberg, 1997), it is not possible to systematically check fidelity to the diary protocol with such reports. For the most part, research teams contribute enough incentive and build trust with participants in order to be confident in the validity of self-report diaries (see Adam, Doane, & Mendelsohn, 2009). However, recent diary studies have started to employ electronic reporting tools (e.g., online surveys, smartphone applications) that offer objective timestamps in order to validate participant adherence, which represent the future direction of EMA research (see Shiffman, Stone, & Hufford, 2008). Timing was of the utmost importance for testing the research questions of this thesis. Participants were asked to report the most stressful experience and provide ratings of affect from the last hour. Cortisol levels reach their peak in saliva approximately 20-25 minutes following a stressor and take up to an hour to return to baseline levels (Adam, 2012; Nicolson, 2008). Thus, there was substantial room for error in the timing of saliva samples and diary reports, which is inherent in naturalistic research with limited control. It is possible these analyses actually underestimated cortisol reactivity to everyday stressors by missing the timing of peak cortisol level. For example, participants might have reported the severity of a stressor that was completed an hour prior to providing a saliva sample, which would have appeared as no or limited cortisol reactivity to that stressor in data analyses. However, the significant association between momentary NA and cortisol demonstrated that the timing was close enough to capture covariation between naturally occurring within-person fluctuations in affect and changes in physiological activity.

Although sophisticated and appropriate statistical methods (hierarchical linear growth models) were used in this thesis, even more rigorous methodological techniques are available. For example, a recent study used multilevel factor analysis and structural equation modeling to assess the relative state and trait contributions of daily diary coping data (Roesch et al., 2010). Such methods provide a rich opportunity for the future study of coping at multiple levels of analysis with larger sample sizes.

Future Directions

Despite novel contributions of this thesis, there are several additional avenues for future research that were not explored here. Following the goodness of fit hypothesis (Folkman & Lazarus, 1980; Forsythe & Compas, 1987), it will be interesting to consider appraisals of stressor controllability in future daily process work examining stress, coping, and cortisol reactivity. Consistent with laboratory findings (Dickerson & Kemeny, 2004), it could be that the association between everyday stress and cortisol reactivity depends on whether or not the stressor is perceived as controllable. Further, the role of coping may function differently in situations considered under one's control compared to those considered beyond one's control. It will also be important to examine the type of stressor (e.g., academic, interpersonal) and objective ratings of stress (Almeida, 2005) in conjunction with coping efforts and cortisol reactivity to better contextualize natural stress processes. It is important to highlight that this thesis focused solely on *engagement* coping responses, given the available measures. Research has demonstrated negative influences of *disengagement* coping (e.g., avoidance) on physiological function, developmental adjustment, and health outcomes (e.g., Compas et al., 2001; Connor-Smith et al., 2000; Hampel & Petermann, 2006). Future research should include an array of engagement and disengagement coping responses in daily diary reports, while balancing the need for brevity when using such methods.

Cortisol is the end product of the HPA axis stress response, which is *one* of the body's stress response systems. Although this thesis extends novel methodological and statistical approaches in the study of cortisol reactivity in naturalistic settings, researchers have recently identified the need to examine multiple stress systems in coordination, interaction, or opposition to one another (Bauer, Quas, & Boyce, 2002; Quas et al., 2014). Of particular interest is salivary alpha amylase (sAA), a surrogate marker of the autonomic nervous system, due to the relative ease with which researchers can assay the same saliva samples for sAA and cortisol (Rohleder, Nater, Wolf, Ehlert, & Kirschbaum, 2004). Researchers have already begun to examine sAA as it relates to cortisol when under stress to determine risk, with the two biomarkers working in either an additive or interactive fashion (e.g., Gordis, Granger, Susman, & Trickett, 2006). There are many exciting avenues for research adopting a multisystems approach with salivary biomarkers in naturalistic settings, including how behavioral coping responses might intersect with multiple stress systems simultaneously.

By examining momentary deviations in cortisol as the outcome, this thesis was not able to make direct links between stress reactivity and health, adjustment, or well-being among first-year college students. Future research might consider how these seemingly small changes in cortisol contribute to more enduring changes in the diurnal pattern of cortisol, as well as how such changes might account for variation in health and adjustment over time. Further research might question whether momentary elevations in cortisol impact physical and psychological health concurrently or prospectively. Of interest might also be whether changes in coping responses (e.g., via intervention efforts), or more enduring developmental changes in self-regulation, modulate the link between cortisol reactivity and health. With the accessibility and advancement of EMA, naturalistic salivary sampling procedures, and requisite statistical modeling techniques, opportunities for future biopsychosocial daily process studies are rich and diverse.

Conclusion

This thesis utilized EMA, naturalistic salivary assessment, and hierarchical linear growth modeling to examine within-person associations between everyday stress, NA, and momentary deviations in HPA axis activity relative to individual diurnal patterns in the daily lives of first-year college students. Building upon limited research in naturalistic settings, coping responses and self-regulation were also explored as moderators at the momentary, daily, and trait level. The findings demonstrated that within-person increases in NA were associated with momentary elevations in salivary cortisol ("cortisol reactivity"). Within-person increases in perceived stress level were associated with momentary increases in cortisol only when first-year students used more engagement coping responses than usual. In contrast, the positive within-person association between stress level and cortisol was significant only for individuals below average on trait coping efficacy and engagement coping. Similarly, the positive within-person association between NA and cortisol was significant only for individuals below average on trait support-seeking coping.

The pattern of findings indicated that HPA axis reactivity to everyday stress and NA depends upon both within-person and between-person differences in coping and self-regulation, albeit in different ways based on the method of assessing everyday stress (perceptions of stress vs. negative affect) and the focal level of analysis. The results have the potential to inform clinicians and university administrators invested in improving the first-year college experience by identifying contextual variation in coping responses and individual differences in self-regulation that contribute to physiological stress regulation. For instance, college transition programs might consider encouraging students' belief in their ability to handle novel everyday demands and identifying positive social outlets through which students can seek support in their new environment. Based on these findings, such initiatives would target evidence-based coping responses that contribute to physiological regulation among first-year college students in their daily lives. Future research can extend these methods by evaluating and improving the measurement of coping responses using EMA, as well as exploring how momentary changes in cortisol correspond to health, adjustment, and emotional well-being across development.

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Table 1

Zero-order correlations among effortful control subscales and measures of individual differences in self-regulation/coping from T1 to T3

Subscale scores	1	2	3	4	5	6	7	8	9	α
1. T1 attentional control	--									.84
2. T1 inhibitory control	.59*	--								.66
3. T1 activation control	.53*	.71*	--							.84
4. T2 attentional control				--						.88
5. T2 inhibitory control				.65*	--					.69
6. T2 activation control				.59*	.61*	--				.87
7. T3 attentional control							--			.90
8. T3 inhibitory control							.60*	--		.63
9. T3 activation control							.58*	.60*	--	.82

Variables	1	2	3	4	5	6	7	8	9	α
1. T1 effortful control	--									.91
2. T2 effortful control	.70*	--								.92
3. T3 effortful control	.78*	.82*	--							.90
4. T1 ego resiliency				--						.64
5. T2 ego resiliency				.70*	--					.77
6. T3 ego resiliency				.60*	.75*	--				.70
7. T1 coping efficacy							--			.85
8. T2 coping efficacy							.65*	--		.91
9. T3 coping efficacy							.51*	.49*	--	.92

Note. $N = 63$. Effortful control scores are the average of subscale scores. * $p < .001$.

Table 2

Pattern matrix coefficients for exploratory factor analysis (EFA)

Item	EFA Loadings	
	F1	F2
I've been trying to come up with a strategy about what to do.	**.82**	-.12
I've been taking action to try to make a situation better.	**.80**	-.02
I've been thinking hard about what steps to take.	**.74**	-.08
I've been concentrating my efforts on doing something about the situation I am in.	**.65**	.14
I've been trying to see it in a different light, to make it seem more positive.	**.55**	-.17
I've been getting help and advice from other people.	-.01	**-.88**
I've been trying to get advice or help from other people about what to do.	.06	**-.82**
I've been getting emotional support from others.	-.08	**-.72**
I've been getting comfort and understanding from someone.	.21	**-.66**

Note. *N* = 71. Factor 1 (F1): engagement coping. Factor 2 (F2): support-seeking coping.

Table 3

Descriptive statistics and zero-order correlations among person-level averages of cortisol, stress, NA, coping, measures of self-regulation, and covariates

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1. Waking levels of cortisol	--																
2. Cortisol awakening response	-.68**	--															
3. Cortisol diurnal slope	-.18	-.02	--														
4. Moment stress	-.01	-.01	-.24†	--													
5. Moment negative affect	-.09	-.06	.19	.34**	--												
6. Moment coping	-.17	-.01	-.22†	.54**	.56**	--											
7. Daily range of coping	-.08	.04	-.19	.16	.40**	.46**	--										
8. Effortful control	-.01	.01	-.22†	.03	-.18	.06	.11	--									
9. Ego resiliency	.17	.02	-.09	.08	-.16	-.01	.02	.69**	--								
10. Coping efficacy	-.03	-.01	-.01	-.03	-.20	.01	-.07	.57**	.61**	--							
11. Engagement coping	.16	-.12	-.17	.12	.14	.38**	.43**	.43**	.49**	.46**	--						
12. Support-seeking coping	-.04	-.10	-.13	.19	.24†	.35**	.29*	.21†	.14	.30*	.41**	--					
13. Non-Hispanic White	-.01	.06	-.40**	.26*	-.02	.11	.26*	.04	-.03	-.08	.04	.20	--				
14. Parent education level	-.20	.28*	-.27*	.12	.02	.15	.28*	.09	.18	.13	.23†	.28*	.22†	--			
15. Oral contraceptive use	-.18	-.13	-.06	-.02	-.07	-.13	.19	.08	-.06	.14	.01	.18	.34**	.29*	--		
16. Sex (1 = male)	.08	.09	.09	.11	.06	.04	-.07	.15	.22†	.18	.09	.11	-.13	-.01	-.38**	--	
17. T2 GPA	-.06	.27*	-.16	.16	.01	.19	.34**	.35**	.31*	.16	.24†	.15	.37**	.50**	.20	-.02	--
M	.25	.55	-.11	1.16	.31	.48	7.36	4.48	6.20	25.30	2.77	2.48		3.28			3.23
(*SD*)[a]	(.66)	(.56)	(.05)	(.46)	(.31)	(.32)	(2.7)	(.72)	(.88)	(3.5)	(.74)	(.78)	47.6	(1.4)	33.0	22.2	(.72)
Range	.04-1.26	-.79-1.83	-.21-.02	.27-2.73	.00-1.48	.00-1.38	.67-11.00	3.07-6.88	3.82-8.52	18.00-32.00	1.20-4.00	1.00-4.00	--	1.00-6.00	--	--	1.09-4.25

Note. $N = 63$. Waking levels of cortisol and cortisol awakening response reported in µg/dl. Cortisol diurnal slope reported as regression-based estimate of linear change in cortisol from waking to bedtime. Unless otherwise noted, all variables assessed at T3 except effortful control, ego resiliency, and coping efficacy, which are composites T1, T2, and T3 scores. Non-Hispanic White (1 = White). Oral contraceptive use (0 = not using, and all males). Parent education level (average of mothers' and fathers' education): 1=completed some high school, 2=high school diploma, 3=some college, 4=associate's degree, 5=bachelor's degree, 6=graduate degree. † $p < .10$. * $p < .05$. ** $p < .01$. [a]Percentages presented for dichotomous variables.

Table 4

Hierarchical linear growth model regression estimates predicting cortisol from momentary stress and NA

	Hypothesis 1					
	Model 1		Model 2		Model 3	
	Est.	*SE*	Est.	*SE*	Est.	*SE*
Intercept: waking cortisol level, γ_{000}	-1.42**	.05	-1.41**	.04	-1.40**	.04
White race/ethnicity, γ_{001}			.23*	.09	.25**	.09
Oral contraceptive use, γ_{002}			-.16†	.08	-.17*	.08
Parental education level, γ_{003}			-.10*	.05	-.10*	.05
Cortisol awakening response, γ_{100}	.56**	.06	.55**	.06	.54**	.06
Oral contraceptive use, γ_{101}			-.33**	.11	-.35**	.11
Parental education level, γ_{102}			.20**	.05	.21**	.05
Time since waking: diurnal slope, γ_{200}	-.11**	.01	-.11**	.01	-.11**	.01
White race/ethnicity, γ_{201}			-.03**	.01	-.03**	.01
Parental education level, γ_{202}			-.01*	.01	-.01*	.01
Momentary stress level, γ_{300}			.03	.02		
Momentary NA, γ_{300}					.06*	.03

Note. 842 moments nested within 63 individuals. Cortisol levels natural logarithmically transformed. Cortisol awakening response (1 = sample provided 30 min after waking, 0 = not sample provided 30 min after waking). Time since waking indicates how long after waking the sample was provided (person and day specific). All other continuous Level 1 and Level 2 predictors were within-person centered and all continuous Level 3 predictors were grand-mean centered. Coefficients are standardized. Results were consistent when controlling for time since waking^2 (curvilinear effect), caffeine and nicotine use at Level 1, wake time and within-person negative affect (for Model 2) at Level 2, and sex and T2 GPA at Level 3. Results were also consistent without controlling for parental education level at Level 3. Est. = regression coefficient estimate. *SE* = robust standard error. NA = negative affect.
†$p < .10$. *$p < .05$. **$p < .01$.

Table 5

Hierarchical linear growth model regression estimates predicting cortisol from momentary stress, NA, and coping

	Hypothesis 2			
	Model 1		Model 2	
	Est.	*SE*	Est.	*SE*
Intercept: waking cortisol level, γ_{000}	-1.45**	.05	-1.41**	.04
White race/ethnicity, γ_{001}	.24**	.09	.24**	.09
Oral contraceptive use, γ_{002}	-.16†	.08	-.16†	.08
Parental education level, γ_{003}	-.11*	.05	-.10*	.05
Cortisol awakening response, γ_{100}	.57**	.06	.55**	.06
Oral contraceptive use, γ_{101}	-.35**	.11	-.33**	.11
Parental education level, γ_{102}	.21**	.05	.20**	.05
Time since waking: diurnal slope, γ_{200}	-.11**	.01	-.11**	.01
White race/ethnicity, γ_{201}	-.03**	.01	-.03**	.01
Parental education level, γ_{202}	-.01*	.01	-.01*	.01
Momentary stress level, γ_{300}	.06†	.03		
Momentary NA, γ_{300}			.07*	.03
Momentary engagement coping, γ_{400}	-.07*	.04	-.04†	.03
Momentary stress x Momentary coping, γ_{500}	.07*	.03		
Momentary NA x Momentary coping, γ_{500}			.01	.03

Note. 842 moments nested within 63 individuals. Cortisol levels natural logarithmically transformed. Cortisol awakening response (1 = sample provided 30 min after waking, 0 = not sample provided 30 min after waking). Time since waking indicates how long after waking the sample was provided (person and day specific). All other continuous Level 1 and Level 2 predictors were within-person centered and all continuous Level 3 predictors were grand-mean centered. Coefficients are standardized. Results were consistent when controlling for time since waking^2 (curvilinear effect), caffeine and nicotine use at Level 1, wake time at Level 2, and sex and T2 GPA at Level 3. The moment stress x moment coping interaction was marginally significant (p = .07) in the model with additional covariates. Results were also consistent without controlling for parental education at Level 3. Est. = regression coefficient estimate. *SE* = robust standard error. NA = negative affect.†p < .10. *$p \leq$ .05. **p < .01.

Table 6

Hierarchical linear growth model regression estimates predicting cortisol from momentary stress, NA, and range of daily coping

	Hypothesis 3			
	Model 1		Model 2	
	Est.	*SE*	Est.	*SE*
Intercept: waking cortisol level, γ_{000}	-1.41**	.04	-1.40**	.04
Range of daily coping, γ_{010}	-.01	.03	-.01	.03
White race/ethnicity, γ_{001}	.24**	.08	.25**	.09
Oral contraceptive use, γ_{002}	-.15†	.08	-.16*	.08
Parental education level, γ_{003}	-.10*	.05	-.10*	.05
Cortisol awakening response, γ_{100}	.55**	.06	.54**	.06
Oral contraceptive use, γ_{101}	-.34**	.10	-.33**	.11
Parental education level, γ_{102}	.20**	.05	.20**	.05
Time since waking: diurnal slope, γ_{200}	-.11**	.01	-.11**	.01
White race/ethnicity, γ_{201}	-.03*	.01	-.03**	.01
Parental education level, γ_{202}	-.01*	.01	-.01*	.01
Momentary stress level, γ_{300}	.03	.02		
Stress x Range of daily coping, γ_{310}	-.05	.04		
Momentary NA, γ_{400}			.07*	.03
NA x Range of daily coping, γ_{510}			-.04	.04

Note. 842 moments nested within 63 individuals. Cortisol levels natural logarithmically transformed. Cortisol awakening response (1 = sample provided 30 min after waking, 0 = not sample provided 30 min after waking). Time since waking indicates how long after waking the sample was provided (person and day specific). All other continuous Level 1 and Level 2 predictors were within-person centered and all continuous Level 3 predictors were grand-mean centered. Coefficients are standardized. Results were consistent when controlling for time since waking^2 (curvilinear effect), caffeine and nicotine use at Level 1, wake time at Level 2, and sex, T2 GPA, and between-person differences in coping at Level 3. Results were also consistent without controlling for parental education at Level 3. Est. = regression coefficient estimate. *SE* = robust standard error. NA = negative affect. †$p < .10$. *$p \leq .05$. **$p < .01$.

Table 7

Hierarchical linear growth model regression estimates predicting cortisol from momentary stress level or momentary NA, depending upon individual differences in various indicators of self-regulation (Hypothesis 4)

	Model 1		Model 2		Model 3		Model 4		Model 5	
	Effortful control		Ego resiliency		Coping efficacy		Engagement coping		Support-seeking coping	
	Est.	*SE*	Est.	*SE*	Est.	*SE*	Est.	*SE*	Est.	*SE*
Intercept: waking level, γ_{000}	-1.41**	.04	-1.41**	.04	-1.41**	.04	-1.41**	.04	-1.41**	.05
White race/ethnicity, γ_{001}	.23*	.09	.24**	.09	.22*	.09	.23**	.08	.25**	.09
Oral contraceptive use, γ_{002}	-.16†	.08	-.15†	.08	-.15†	.08	-.16†	.08	-.16†	.09
Parental education level, γ_{003}	-.10*	.05	-.12*	.05	-.11*	.05	-.11*	.05	-.09†	.05
Between-person self-regulation, γ_{004}	-.01	.03	.06†	.04	-.04	.03	.05	.04	-.04	.05
Cortisol awakening response, γ_{100}	.55**	.06	.55**	.06	.55**	.06	.55**	.06	.55**	.06
Oral contraceptive use, γ_{101}	-.33**	.11	-.34**	.11	-.35**	.11	-.34**	.11	-.34**	.11
Parental education level, γ_{102}	.20**	.05	.20**	.05	.20**	.05	.20**	.05	. 20**	.05
Time since waking: diurnal slope, γ_{200}	-.11**	.01	-.11**	.01	-.11**	.01	-.11**	.01	-.11**	.01
White race/ethnicity, γ_{201}	-.03*	.01	-.03*	.01	-.03**	.01	-.03*	.01	-.03**	.01
Parent education, γ_{202}	-.01*	.01	-.01*	.01	-.01†	.01	-.01*	.01	-.01*	.01
Momentary stress level, γ_{300}	.03	.02	.03	.02	.03	.02	.03	.02		
Stress x Between-person self-regulation, γ_{301}	-.02	.02	-.02	.03	**-.05***	**.02**	**-.06***	**.03**		
Momentary NA, γ_{300}									.06*	.03
NA x Between-person self-regulation, γ_{301}									**-.07****	**.03**

Note. 842 moments nested within 63 individuals. Cortisol levels natural logarithmically transformed. Cortisol awakening response (1 = sample provided 30 min after waking, 0 = not sample provided 30 min after waking). Time since waking indicates how long after waking the sample was provided (person and day specific). All other continuous Level 1 and Level 2 predictors were within-person centered and all continuous Level 3 predictors were grand-mean centered. Coefficients are standardized. Results were consistent when controlling for time since waking^2 (curvilinear effect), caffeine and nicotine use at Level 1, wake time at Level 2, and sex and T2 GPA at Level 3. Results were also consistent without controlling for parental education at Level 3. Est. = regression coefficient estimate. SE = robust standard error. NA = negative affect.
†*p* < .10. **p* ≤ .05. ***p* < .01.

Table 8

Compliance considerations: Primary findings from hierarchical linear growth models across 3 samples

	Sample 1		Sample 2		Sample 3	
	N = 70		*N* = 63		*N* = 60	
	Est.	*p*	Est.	*p*	Est.	*p*
Momentary NA main effect (reactivity)	.06	.03	.06	.03	.06	.04
Momentary coping main effect	-.06	.08	-.07	.05	-.07	.04
Moment-level stress x moment-level coping	.04	.12	.07	.02	.07	.03
Moment-level stress x person-level coping efficacy	-.04	.05	-.05	.02	-.06	.02
Moment-level stress x person-level engagement coping	-.04	.08	-.06	.02	-.06	.04
Moment-level NA x person-level support-seeking coping	-.04	.09	-.07	<.01	-.07	<.01

Note. Sample 1 includes all 70 participants in analyses who adequately provided data (1 participant removed for failing to provide diary data). Sample 2 excludes participants and specific saliva sample data deemed not compliant but includes 3 participants who did not use the electronic track cap (compliance information unavailable). Sample 3 represents the most strict compliance parameters: all participants and specific samples excluded and 3 participants who did not use the track cap excluded. Est. = regression coefficient estimate. NA = negative affect.

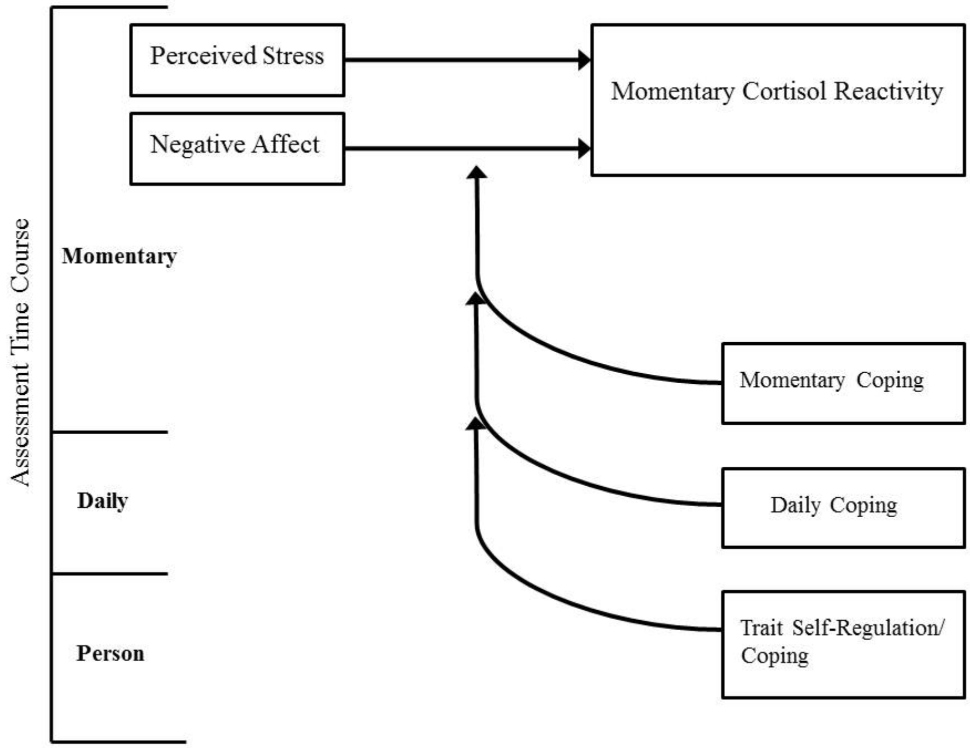

Figure 1. Conceptual model. Within-person associations between momentary perceived stress level and negative affect and momentary cortisol reactivity assessed naturalistically as the deviation in cortisol level from an individual's diurnal rhythm. These momentary associations moderated by within-person momentary engagement coping responses, range of daily engagement coping responses, and individual differences in self-regulation and coping.

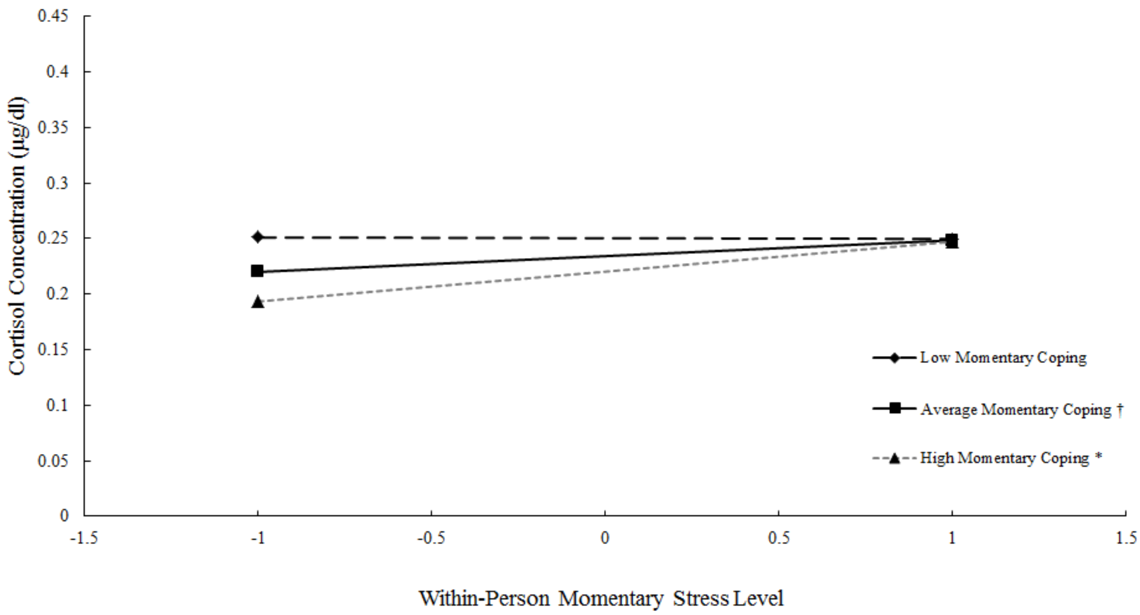

Figure 2. Simple slope plots of momentary cortisol by momentary stress level at the within-person mean and 1 *SD* above and below the within-person mean of momentary engagement coping. † $p < .10$. * $p < .05$.

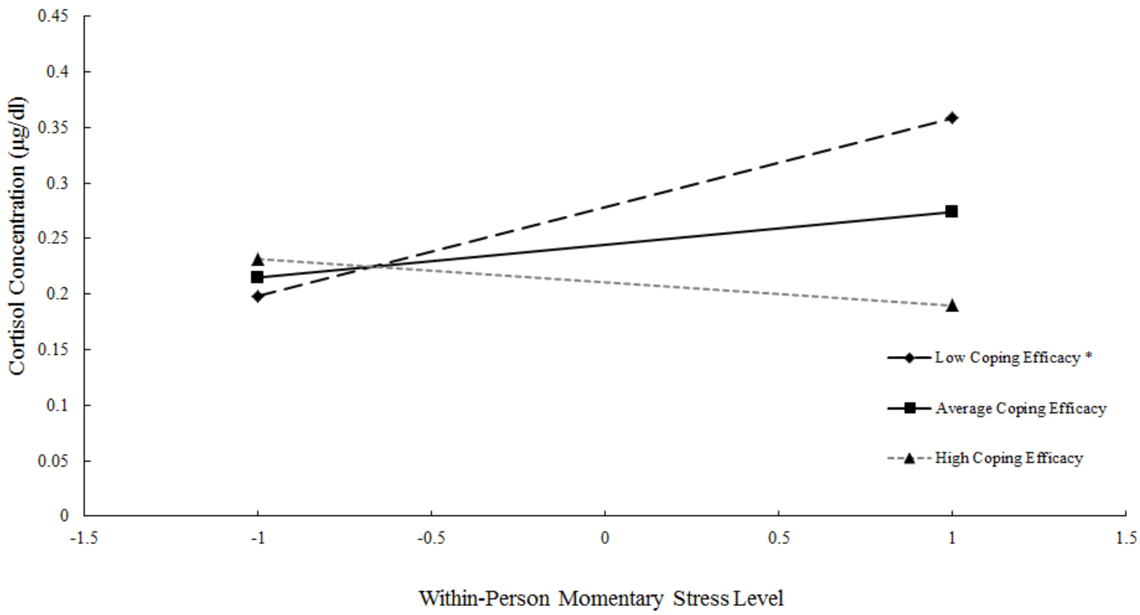

Figure 3. Simple slope plots of momentary cortisol by momentary stress level at the sample mean and 1 *SD* above and below the mean of person-level coping efficacy.
* $p < .05$.

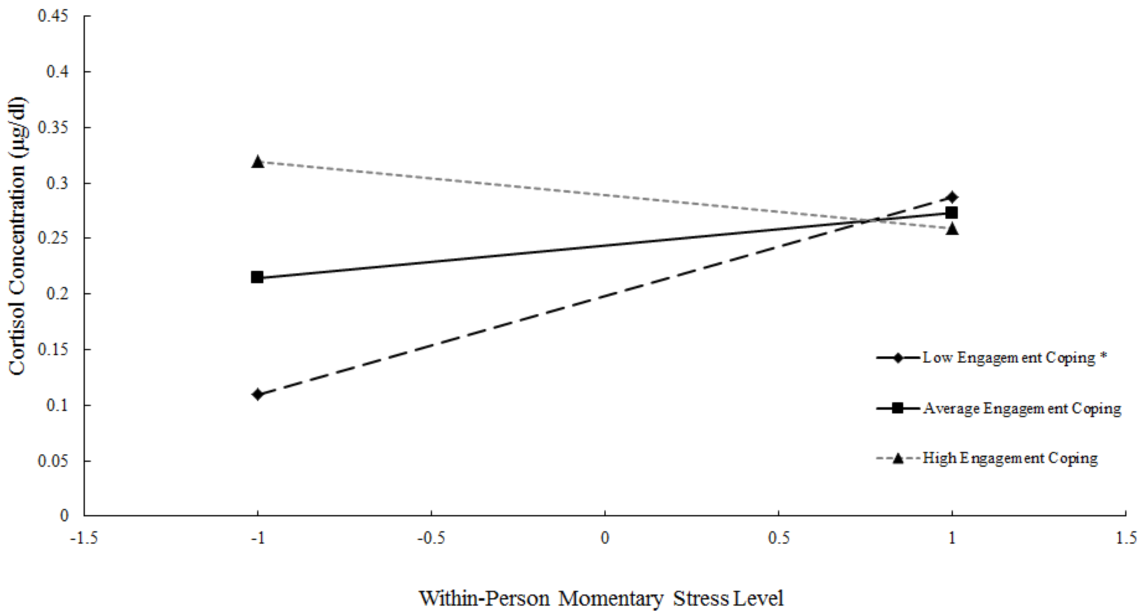

Figure 4. Simple slope plots of momentary cortisol by momentary stress level at the sample mean and 1 *SD* above and below the mean of person-level engagement coping.
* $p < .05$.

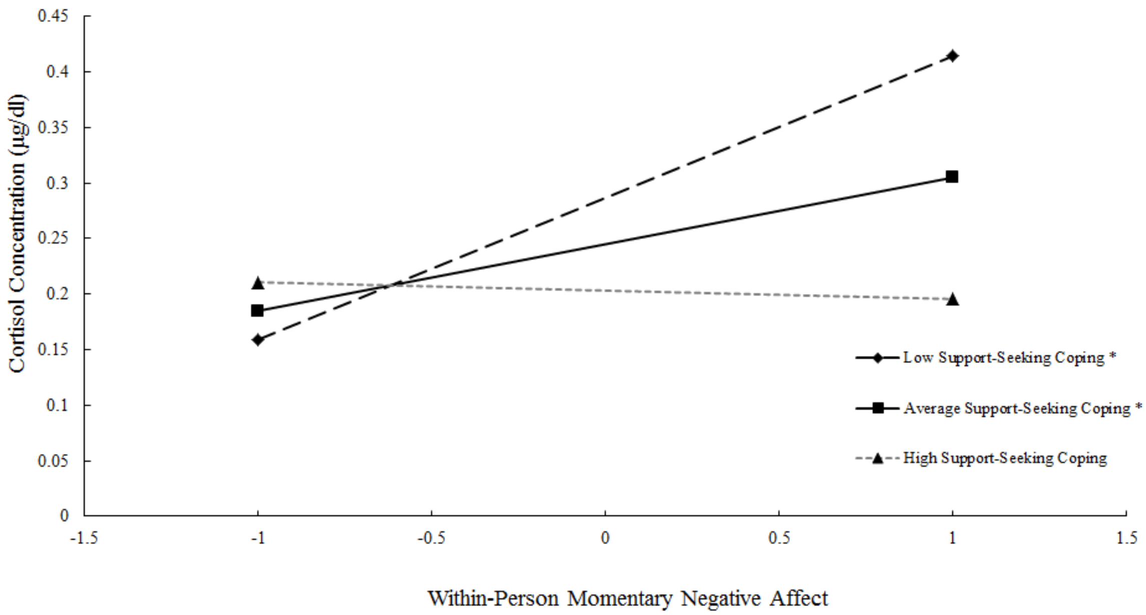

Figure 5. Simple slope plots of momentary cortisol by momentary NA at the sample mean and 1 *SD* above and below the mean of person-level support-seeking coping.
* $p < .05$.

APPENDIX A

NON-COMPLIANT PARTICIPANTS (n = 7)

Case 1: no compliant waking samples, all 3 track cap-detected waking samples were > 15 min after actigraph get up time

Case 2: no compliant waking samples, all 3 track cap-detected waking samples were > 15 min after actigraph get up time

Case 3: no compliant waking samples, no actigraph times available for Day 1, other 2 waking samples were > 15 min after actigraph get up time

Case 4: no compliant waking samples, all 3 track cap-detected waking samples were > 15 min after actigraph get up time

Case 5: no compliant waking samples, all 3 track cap-detected waking samples were > 15 min after actigraph get up time

Case 6: no compliant waking or CAR samples, Day 1 no morning track cap times available (to determine compliance for waking or CAR samples), Day 2 no track cap detected times, Day 3 track cap-detected waking and CAR samples > 15 min after actigraph get up time

Case 7: no compliant waking or CAR samples, Day 1 no actigraph times available, Days 2 and 3 track cap-detected waking samples > 15 min after actigraph get up time (and track cap-detected CAR samples more than 37 min after wake)

APPENDIX B

MEASURES

Momentary Stress Diary Questions

Describe the **most stressful situation or event** you encountered in the past hour.

____

How **stressful** was this event?

Not at all	A little	Somewhat	Very
0	1	2	3

Momentary Negative Affect Diary Questions

PANAS (Watson et al., 1988)

Indicate to what extent you felt each of the following emotions within the last hour:

	Very slightly or not at all	A little	Moderately	Quite a bit	Extremely
Distressed	0	1	2	3	4
Upset	0	1	2	3	4
Guilty	0	1	2	3	4
Scared	0	1	2	3	4
Hostile	0	1	2	3	4
Irritable	0	1	2	3	4
Ashamed	0	1	2	3	4
Nervous	0	1	2	3	4
Jittery	0	1	2	3	4
Afraid	0	1	2	3	4

Momentary Coping Diary Questions

Adapted for diary format from Brief COPE (Carver, 1997) and Responses to Stress Questionnaire (Connor-Smith et al., 2000)

How much did your response include the following:	Not at all	A little	Somewhat	Very
Distracting myself with thoughts or activities	0	1	2	3
Thinking of a solution or gathering information	0	1	2	3
Doing something to solve the situation	0	1	2	3
Expressing my feelings to reduce tension	0	1	2	3
Accepting it, there is nothing to be done	0	1	2	3
Seeking emotional support from others	0	1	2	3
Doing something to relax	0	1	2	3
Giving up trying to deal with it	0	1	2	3

Daily Coping Diary Questions

Modified for diaries from Responses to Stress Questionnaire (Connor Smith et al., 2000)

Overall today, how much did you….

a. focus on your feelings? (*Engagement primary control: emotion regulation)*

Not at all	A little	Some	A lot
0	1	2	3

b. focus on your problems/stress today? *(Engagement primary control: problem solving)*

Not at all	A little	Some	A lot
0	1	2	3

c. ask other people for help or for ideas about how to make your problems/stress better? (*Engagement primary control: emotional expression)*

Not at all	A little	Some	A lot
0	1	2	3

d. let your feelings out? *(Engagement primary control: emotional expression)*

Not at all	A little	Some	A lot
0	1	2	3

e. get help from other people to try to figure out how to deal with your feelings? (*Engagement primary control: emotional regulation)*

Not at all	A little	Some	A lot
0	1	2	3

f. try to fix your problems or take action to change things? (*Engagement primary control: problem solving)*

Not at all	A little	Some	A lot
0	1	2	3

g. do something to calm yourself down to deal with your problems? (*Engagement primary control: emotional regulation)*

Not at all	A little	Some	A lot
0	1	2	3

h. keep your feelings under control when you had to, then let them out when they didn't make things worse? (*Engagement primary control: emotional regulation)*

Not at all	A little	Some	A lot
0	1	2	3

i. tell yourself that everything would be all right? (*Engagement secondary control: positive thinking)*

Not at all	A little	Some	A lot
0	1	2	3

j. tell yourself that things could be worse? (*Engagement secondary control: cognitive restructuring)*

Not at all	A little	Some	A lot
0	1	2	3

k. try to just take things as they are, go with the flow? (*Engagement secondary control: acceptance)*

Not at all	A little	Some	A lot
0	1	2	3

Effortful Control

Effortful Control scale of Adult Temperament Questionnaire (Evans & Rothbart, 2008)

On the following pages you will find a series of statements that individuals can use to describe themselves. There are no correct or incorrect responses. All people are unique and different, and it is these differences which we are trying to learn about. Please read each statement carefully and give your best estimate of how well it describes you. Check the appropriate number below to indicate how well a given statement describes you.

Check #:	if the statement is:
1	extremely untrue of you
2	quite untrue of you
3	slightly untrue of you
4	neither true nor false of you
5	slightly true of you
6	quite true of you
7	extremely true of you

If one of the statements does not apply to you (for example, if it involves driving a car and you don't drive), then check "X" (not applicable).

1. If I want to, it is usually easy for me to keep a secret.
2. It is easy for me to hold back my laughter in a situation when laughter wouldn't be appropriate.
3. When I see an attractive item in a store, it's usually very hard for me to resist buying it.
4. I can easily resist talking out of turn, even when I'm excited and want to express an idea.
5. When I decide to quit a habitual behavioral pattern that I believe to be undesirable, I am usually successful.
6. When I'm excited about something, it's usually hard for me to resist jumping right into it before I've considered the possible consequences.
7. Even when I feel energized, I can usually sit still without much trouble if it's necessary.
8. I often avoid taking care of responsibilities by indulging in pleasurable activities.
9. At times, it seems the more I try to restrain a pleasurable impulse (e.g., eating candy), the more likely I am to act on it.
10. I usually have trouble resisting my cravings for food drink, etc.
11. It is easy for me to inhibit fun behavior that would be inappropriate.
12. I usually finish doing things before they are actually due (e.g., paying bills, finishing homework, etc.).
13. I am often late for appointments.

14. I often make plans that I do not follow through with.
15. As soon as I have decided upon a difficult plan of action, I begin to carry it out.
16. If I think of something that needs to be done, I usually get right to work on it.
17. I can make myself work on a difficult task even when I don't feel like trying.
18. Even when I have enough time to complete an activity today, I often tell myself that I will do it tomorrow.
19. If I notice I need to clean or wash something (e.g., car, apartment, laundry, etc.), I often put it off until tomorrow.
20. I hardly ever finish things on time.
21. I usually get my responsibilities taken care of as soon as possible.
22. When I am afraid of how a situation might turn out, I usually avoid dealing with it.
23. I can keep performing a task even when I would rather not do it.
24. When I am sad about something, it is hard for me to keep my attention focused on a task.
25. When I am anxious about the outcome of something, I have a hard time keeping my attention focused on a task.
26. It is very hard for me to focus my attention when I am distressed.
27. When I am happy and excited about an upcoming event, I have a hard time focusing my attention on tasks that require concentration.
28. When I am especially happy, I sometimes have a hard time concentrating on tasks that require me to keep track of several things at once.
29. When I hear good news, my ability to concentrate on taking care of my responsibilities goes out the window.
30. When I am trying to focus my attention, I am easily distracted.
31. When trying to focus my attention on something, I have difficulty blocking out distracting thoughts.
32. When trying to study something, I have difficulty tuning out background noise and concentrating.
33. When interrupted or distracted, I usually can easily shift my attention back to whatever I was doing before.
34. I am usually pretty good at keeping track of several things that are happening around me.
35. It’s often hard for me to alternate between two different tasks.

Ego Resiliency

(Block & Block, 1980; Eisenberg et al., 2003)

Please rate how accurately each item describes you. Please use this scale and check the appropriate number for each item.
1 = most undescriptive
2 = very undescriptive
3 = quite undescriptive
4 = somewhat undescriptive
5 = neither descriptive or undescriptive
6 = somewhat descriptive
7 = quite descriptive
8 = very descriptive
9 = most descriptive

1. I am resourceful in initiating activities (finding ways to make things happen and get things done).
2. I freeze up when things are stressful, or else I keep doing things over and over again.
3. I am curious and like to explore; I like to learn and experience new things.
4. I can bounce back or recover after a stressful or bad experience.
5. When under stress, I give up and back off.
6. I have specific mannerisms or behavior rituals (e.g. I always tap my fingers, bite my fingernails or bite my lips).
7. I tend to get sick when things go wrong or when there is a lot of stress (for example, gets headaches, stomach aches, throws up).
8. I tend to go to pieces under stress; becomes rattled and disorganized when things are chaotic.
9. I can talk about unpleasant things that have happened to me.
10. I am creative in the ways I look at things; the way I work or relax is very creative.
11. I use and respond to reason (think things out before m making decisions).

Coping Efficacy Scale (Sandler et al., 2000)

Sometimes things that people do to handle their problems work really well to make their problems better and sometimes they don't work at all to make them better. Overall, how successful have you been in handling your problems?

Not at all	1
A little bit successful	2
Fairly successful	3
Very successful	4

Overall, how well do you think that the things you did worked to make your problem situations better?

Did not work at all	1
Worked a little	2
Worked pretty well	3
Worked very well	4

Sometimes things people do to handle their problems work really well to make them feel better and sometimes they don't work at all to make them feel better. Overall, how well do you think that the things you did worked to make you feel better?

Did not work at all	1
Worked a little	2
Worked pretty well	3
Worked very well	4

Overall, how satisfied are you with the way you handled your problems?

Not at all satisfied	1
A little satisfied	2
Pretty well satisfied	3
Very satisfied	4

Overall, compared to other people, how good do you think that you have been in handling your problems?

Not at all good	1
A little good	2
Pretty good	3
Very good	4

In the future, how good do you think that you will usually be in handling your problems?

Not at all good	1
A little good	2
Pretty good	3
Very good	4

Overall, how good do you think you will be at making things better when problems come up in the future?

Not at all good	1
A little good	2
Pretty good	3
Very good	4

Overall, how good do you think you will be at handling your feelings when problems come up in the future?

Not at all good	1
A little good	2
Pretty good	3
Very good	4