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Assessing Daily Stress Processes in Social Surveys by Combining Stressor Exposure and Salivary Cortisol

David M. Almeida[1], **Katherine McGonagle**[2], and **Heather King**[1]

[1]Department of Human Development and Family Studies, Pennsylvania State University

[2]Survey Research Center, Institute for Social Research, University of Michigan

Abstract

This paper presents a research method for assessing stress and mental health in ongoing population-based social surveys that combines self-reports of naturally occurring daily stressors with a primary marker of stress physiology, salivary cortisol. We first discuss the relevance of stress processes to mental health and introduce a model for examining daily stress processes, which highlights multiple components of daily stressor exposure. A primary aim of this approach is to capture variability across stressful situations, between persons of different groups, or within persons over a period of time. Next, we describe how the assessment of diurnal salivary cortisol is a promising approach to examining naturally occurring stress physiology in large social surveys. We then present findings from the National Study of Daily Experiences (a substudy of the Midlife in the United States Study) that document the feasibility and reliability of the collection of daily stressors and salivary diurnal cortisol and provide examples of research findings linking stressor exposure to diurnal cortisol. The final portion of the paper describes ways that this approach can leverage the strengths of various features of longitudinal social surveys to extend research on stress and mental health.

There are features and events in the daily environment that pose risks to mental health and psychological well-being such as demanding work conditions, financial pressures, and work-family conflicts. Often referred to as daily stressors or hassles, these events represent tangible, albeit minor interruptions that may have a more proximal effect on well-being than major life events such as job loss and divorce (Lazarus, 1999). Although daily stressor exposure is associated with poorer well-being, it has been harder to establish with precision how specific features and events in the daily environment contribute to poorer well-being. It may not be enough to simply know if a stressor occurred, but rather to consider multiple aspects of the stressful event as well the physiological response to the event (Almeida, 2005). This paper presents a research method that combines self-reports of naturally occurring daily stressors with a biological marker of stress physiology, salivary cortisol. Research on stress physiology often occurs in laboratory settings where researchers experimentally manipulate stressor exposure and have a great deal of control over the measurement of the physiological response. We believe that the daily stress approach holds promise for researchers interested in understanding naturally occurring stress processes in large social surveys. Challenges regarding the feasibility, reliability, and validity of assessments are addressed with examples from The National Study of Daily Experiences (NSDE) a substudy of the Midlife in the United States Study (MIDUS). The scientific potential of the daily stressor approach is illustrated by several examples of research findings linking stressor exposure to diurnal cortisol. Finally, ways that this approach can leverage the strengths of various features of longitudinal social

Mail correspondence to :David Almeida, Department of Human Development and Family Studies, The Pennsylvania State University, 118 Henderson Building, University Park, PA 16802; Phone: (814) 865-2656; Fax: (814) 863-9423; dalmeida@psu.edu.

surveys to extend research on stress and mental health are described, along with a brief discussion of ethical concerns that may arise with the collection of salivary cortisol.

Stress and Mental Health

Exposure to stressful situations is associated with aspects of mental health and affective well-being such as psychological distress (Almeida & Kessler, 1998; Serido, Almeida, & Wethington, 2004) as well as negative mood and depressive symptoms (Bolger, DeLongis, Kessler, & Shilling, 1989; McGonagle & Kessler, 1990). In addition, the extant literature suggests stressors are linked to more serious reactions and conditions such as depression, for example (for a review, see Hammen, 2005). Both stressor exposure and reactivity have been implicated in the relation between stress and depression; models attempting to explain the stress-depression association include sociodemographic, developmental, psychological as well as biological mediators and moderators (Hammen, 2005).

It has long been known that major life events such as job loss, marital disruption, and death of a loved one adversely affect psychological and physical health (Brown & Harris, 1989; Dohrenwend & Dohrenwend, 1974; Holmes & Rahe, 1967; Hultsch & Plemons, 1979). An emerging literature has shown that day-to-day stressors such as spousal conflict and work deadlines also play an important part in health and emotional adjustment (for a review, see Stone, 1992). Daily stressors exhibit immediate effects on emotional and physical functioning on the day they occur (see reviews by Pearlin, Lieberman, Menaghan, & Mullan, 1981; Almeida, 2005; Zautra, 2003) and create aggregated effects that increase vulnerability to problems including anxiety and depression (Lazarus, 1966, 1999; Lazarus & DeLongis, 1983; Lazarus & Folkman, 1984; Pearlin & Schooler, 1978; Zautra, Guarnaccia, & Dohrenwend, 1986).

Daily stressors also mediate and magnify the effects of major stressful events. Mediation can occur when a major stressful event leads to increased day-to-day stressors which, in turn, add to the overall effect of the major event on health. This process was illustrated by Felner and colleagues (Felner, Rowlison, & Terre, 1986; Rowlison & Felner, 1988), who view major life events as transitional markers that often disrupt established daily activities, formerly shared responsibilities, and day-to-day social relations, thereby increasing psychological distress. The emotional and physical impact of minor day-to-day stressors can also be magnified in the context of a major life event by representing the proverbial straw that broke the camel's back (e.g., an objectively small, but insurmountable, financial difficulty caused by a breakdown of the family's only car in the wake of the chief breadwinner's job loss). Major life events can also take on new meaning in the context of a matching event that makes the minor event seem much more important than it would be to the average person (e.g., a minor disagreement with a coworker coinciding with a conflictual marital breakup; Brown & Harris, 1978).

Taking a Daily Approach to Mental Health

While most information on mental health obtained from population-based social surveys has relied on retrospective and current assessments of affective functioning, typically collected at a single point in time using continuous scales such as the CES-D (Radloff, 1977) or K-6 (Kessler et al., 2003), for example, the approach described here is one that assesses well-being on a daily basis. This approach is embedded in current theories of health that argue that understanding global aspects of well-being requires careful consideration of behaviors and experiences at a more micro level (Kahneman, Krueger, Schkade, Schwarz, & Stone, 2004; Ram et al., 2005). Such an approach also provides a unique opportunity to examine stress adaptation (i.e., how people modify their behaviors to accommodate change over time), which would be synergistic with the examination of the effect of stress on physical health. There is growing evidence showing that repeated stress adaptation may, over time, lead to physical

disease via a suppressed immune response (e.g., infection) as well as over-activation of immune responses (e.g., allergic and autoimmune responses; Segerstrom & Miller, 2004). Such findings highlight the importance of including daily physiological measures of ongoing adaptation to a dynamic environment to complement self-report data.

Daily mental health can be measured in terms of *affective well-being*. Affect is particularly useful for measuring psychological well-being because the preponderance of positive and negative affect comes closest to an everyday meaning of well-being, or lack thereof (Diener, 1984; Diener, Suh, Lucus, & Smith, 1999). Most researchers have relied on respondents' global reports of well-being, typically recalled over months or years. Global reports, however, are moderately correlated with personality traits and seem to be relatively stable (Costa, Somerfield, & McCrae, 1996; Diener, 1984). An advantage of daily reporting is the ability to assess intraindividual variability, or the extent to which people fluctuate around their own average levels of well-being (Cervone, 2004; Lykken & Tellegen, 1996). Measuring affective well-being over shorter time frames has other advantages as well. The length of the recall period systematically influences how people recall emotions (Winkielman, Knauper, & Schwartz, 1998) with longer reference periods prone to a systematic bias for recall of more intense emotional experiences. For example, weekly retrospective reports overestimate the intensity of both positive and negative affect as compared to daily reports of affect averaged across a week (Thomas & Diener, 1990).

An emerging literature documents the effects of day-to-day stressors such as spousal conflict and work deadlines on psychological distress (Bolger, Davis, & Rafaeli, 2003; Stone, 1992; Zautra, 2003). For example, research confirms that individuals are more likely to report psychological distress and physical symptoms on days they experience stressors compared to stressor-free days (Almeida, 2005). Specific types of daily stressors, such as interpersonal tensions and network stressors, are more predictive of psychological distress than other types of stressors. Furthermore, stressors that disrupt daily routines or pose risks to physical health and safety are particularly distressing (Almeida, 2005). This body of research has focused largely on self-reported health and daily stressors; results are commonly qualified by discussions of possible response biases and questions concerning the validity of self-reported health measures. Although self-reported health has been found to be an accurate indicator of health and sometimes a better predictor of mortality than more objective measures (Bernard et al., 1997; Mossey & Shapiro, 1982; Schoenfeld, Malmrose, Blazer, Gold, & Seeman, 1994), questions remain regarding the direct relation between daily stressors, physiological functioning and well-being. Research has addressed this issue by assessing day-to-day variation in salivary cortisol (Adam, Hawkley, Kudielka, & Cacioppo, 2006).

Cortisol as a Biomarker of Daily Stress Processes

Physical or psychological stress can increase corticotrophin-releasing hormone, activate the hypothalamic-pituitary-adrenal (HPA) axis, and promote secretion of glucocorticoids (e.g., cortisol) into circulation. Persistently elevated levels of cortisol or non-response of cortisol levels to laboratory challenges (blunted sensitivity) are symptomatic of general poor physical health, generally interpreted as wear and tear on the HPA-axis (Kiecolt-Glaser, Garner, Speicher, Penn, & Glaser, 1986; Segerstrom & Miller, 2004). Less is known, however, about links between naturally occurring stressors and cortisol. Saliva contains concentrations of cortisol, and salivary assessment is a relatively non-invasive method for obtaining accurate measurements of this particular stress hormone and thus permits exciting opportunities to assess stress physiology outside of the laboratory (Granger & Kivlighan, 2003).

The daily stress approach highlights the diurnal rhythm of salivary cortisol; it typically peaks shortly after waking in the morning (i.e. the cortisol awakening response) then gradually

declines throughout the rest of the day. This diurnal rhythm of cortisol provides information about individuals' chronobiology (Keenan, Licinio, & Veldhuis, 2001) and may provide the best window into stress physiology, providing information about overall levels and fluctuations in cortisol across the day, and the association of these characteristics of cortisol with exposure to stressful experiences and individual/contextual factors (van Eck, Berkhof, Nicolson, & Sulon, 1996).

If the cortisol rhythm becomes perturbed, other biological rhythms may be dysregulated such as lymphocyte production (i.e., immune system regulation), basal body temperature, and sleep (Cugini, Romit, di Palma, & Giacovazzo, 1990). In addition, the early and late afternoon levels of cortisol reflect daily engagement and disengagement of the brain with peripheral physiology and hence, the external environment (Chahal & Drake, 2007). Failure to activate the HPA axis in the morning and deactivate in the evening may indicate difficulty from disengaging from external demands, leading to inhibition of restoration and recovery processes (Sapolsky, Krey, & McEwen, 1986).

Short-increases in cortisol are thought to reflect a "normal" physiological response to stressor exposure (Sapolsky et al., 1986). However, characteristics of stressor experiences or the individual's exposure to stressful situations may influence the magnitude of such responses, leading to exaggerated (hyper) or diminished (hypo) responsiveness. The impact of variations in cortisol stress reactivity are thought to cumulate over time, in response to repeated or chronic stressor exposure leading to persistent high or low levels of circulating cortisol (which in turn can influence multiple aspects of physiological functioning). Persistently elevated levels of cortisol or hyper- or hypo-responsive cortisol stress reactivity are symptomatic of general poor physical health, often interpreted as wear and tear on the HPA axis (Kiecolt-Glaser et al., 1986; Segerstrom & Miller, 2004).

Cortisol as a Marker of Mental Health

Dysregulation of the hypothalamic-pituitary-adrenal (HPA) axis, specifically hypercortisolism, appears to play an important role in mediating stressful experiences and the etiology of depression (Carroll et al., 2007; Gotlib, Joorman, Minor, & Hallmayer, 2008; Wong et al., 2000). The corticosteroid receptor (CR) hypothesis of depression argues that CR signaling and function is impaired and decreased in depressed individuals, which increases production and secretion of corticotrophin-releasing hormone (Holsboer, 2000, 2001). A number of studies have found that depressed individuals have higher cortisol levels (hyperactivity) during the recovery period following exposure to a stressor as compared to non-depressed individuals (for review, see Burke, Davis, Otte, & Mohr, 2005).

There is some evidence, however, that depression is associated with hypoactivity of the HPA axis and blunted cortisol reactivity in certain depressed individuals such as older adults (Bremmer et al., 2007; Burke et al., 2005). Perhaps in depressed, older individuals the experience of chronic stress and depression contributes to hypocortisolism given wear and tear on the body over time (allostatic load). In fact, hypocortisolism has been linked to chronic stress, burnout, and chronic fatigue syndrome (Cleare, 2004; Heim, Ehlert, & Hellhammer, 2000; Pruessner, Hellhammer, & Kirschbaum, 1999; Roberts, Wessely, Chalder, Papadopoulos, & Cleare, 2004). The association between stress and depression as well as other features of mental health and affective well-being is clearly complex and additional research is needed to further elucidate these links.

Daily Stressors and Diary Designs

The understanding of daily stress processes has benefited from the development of diary methods that obtain repeated measurements from individuals during their daily lives. One

approach, Ecological Momentary Assessment (EMA) involves using electronic pagers or hand held computers (e.g., PDAs) that prompt respondents to record experiences at the moment they are paged or over a certain interval. This strategy is excellent for assessing ongoing or frequent experiences such as mood and heath behaviors but not as effective at capturing less frequent experiences such as stressful events. EMA also involves training participants to use devices and thus creates logistical problems in large studies when there is little or no face to face contact with participants (Almeida, 2005). Another daily strategy is the use of short questionnaires or telephone interviews, where individuals report on the stressors they experienced on that day as well as the behaviors, physical symptoms, and emotional states experienced during that same time frame. The number of days and the number of respondents vary greatly across studies. For example, the Vienna Diary Study followed 40 couples every night over the course of an entire year (Kirchler, Rodler, Hölzl, & Meier, 2001) while the National Study of Daily Experiences assessed the daily lives of 2022 adults across United States on eight consecutive evenings (Almeida, Wethington, & Kessler, 2002). Diary methods have a number of virtues (Bolger et al., 2003). By obtaining information about individuals' actual daily stressors over short term intervals they circumvent concerns about ecological validity that constrain findings from laboratory research. Further, diary methods alleviate retrospective memory distortions that can occur in more traditional questionnaire and interview methods that require respondents to recall experiences over longer time frames.

Perhaps the most valuable feature of diary methods is the ability to assess *within-person stressor reactivity. Stressor reactivity* is the emotional or physical reaction to daily stressors (Almeida, 2005; Bolger & Zuckerman, 1995; Cacioppo, 1998). In this sense, stressor reactivity is not defined as well-being (i.e., negative affect or physical symptoms), but the change in well-being associated with the experience of daily stressors, and it is operationalized as the within-person relationship between stressors and well-being. Reactivity, therefore, is a dynamic process that links stressors and well-being over time. Previous research indicates that people who are more reactive to daily stressors are more susceptible to physical disease than are people who are less reactive to stressors (Cacioppo, 1998).

The daily stress approach represents a shift from assessing mean levels of stressors and well-being between individuals to charting the day-to-day fluctuations in stress and well-being within an individual. Stress is a process that occurs within the individual, and research designs need to reflect this process. For example, instead of asking whether individuals with high levels of work stress experience more distress than individuals with less stressful jobs, a researcher can ask whether a worker experiences more distress on days when he or she has too many deadlines (or is reprimanded) compared to days when their work has been free of stress. This within-person approach allows the researcher to rule out temporally stable personality and environmental variables as third variable explanations for the association between stressors and well-being. In addition, the intensive longitudinal aspect of this design permits a temporal examination of how stressors are associated with changes in well-being from one day to the next. By establishing within-person associations over time between daily stressors and well-being, researchers can more precisely establish the short-term effects of concrete daily experiences (Bolger et al., 2003).

As stated earlier, research documents the effects of day-to-day stressors such as spousal conflict and work deadlines on health status (Bolger et al., 2003; Stone, 1992; Zautra, 2003). This research has focused largely on self-reported health and daily stressors; results are commonly qualified by discussions of possible response biases and questions concerning the validity of self-reported health measures. A number of studies, however, have examined the link between characteristics of daily stressors and salivary cortisol in smaller community- based homogenous samples. For example, the pioneering work of van Eck and colleagues (1996) utilized ecological momentary assessments to investigate the association between daily

stressors and levels of salivary cortisol among a sample of 87 male, white-collar employees. Self-reports of stressful events as well as saliva samples were obtained 10 times a day for 5 days. Cortisol levels were higher on occasions when participants had experienced a stressor since the previous occasion (van Eck et al., 1996). Other studies have also employed daily diary designs to examine the relation between salivary cortisol and the anticipation of and response to specific daily stressors. Nicolson (1992) examined cortisol reactivity in relation to various types of examinations such as a driving test. Levels of salivary cortisol significantly increased, relative to baseline, directly before the examination (Nicolson, 1992). These and other studies laid the foundation for additional work in this area and inform future investigations with larger and more heterogeneous participants and stressors. To this end we turn our attention to the feasibility and promise of collecting daily data on stressor exposure and the diurnal rhythm of salivary cortisol in large social surveys.

Assessing Daily Stressors and Diurnal Cortisol in the Field

The vast majority of past research on stress physiology has occurred in laboratory settings where researchers often experimentally manipulate stressor exposure and have a great deal of control over the measurement of the physiological response. There is an emerging interest in collecting cortisol in larger field studies (for a recent review, see Adam & Kumari, in press). We believe that our approach holds promise for researchers interested in understanding naturally occurring stress processes in large social surveys such as the Panel Study of Income Dynamics, a nationally representative longitudinal study of US families. Of course this promise comes with great challenges surrounding the feasibility, reliability, and validity of assessments. Using our experience implementing The National Study of Daily Experiences (NSDE) and some initial findings, we attempt to address these challenges.

The NSDE is telephone diary study that collects information on daily stressors and well-being on eight consecutive evenings. The second wave of NSDE data collection obtained 16 samples of salivary cortisol (4 samples per day for 4 of the 8 days). We present rates of participation from the NSDE and correlations across various modes of timing of collection in the saliva collection protocol as evidence of feasibility and reliability of this method. We then compare findings from the NSDE to findings from studies that have more control over daily saliva collection to determine if lack of control compromised the validity of cortisol measurement. We also present preliminary findings that assess the day-to-day within-person temporal covariation of daily stressors with diurnal cortisol. Establishing within-person daily covariation between stressors and cortisol helps validate the short-term physical effects of concrete daily experiences. These findings provide evidence for the feasibility, reliability, and validly of a daily stressor approach that potentially lends insight into how stressors contribute to affective well-being.

Description of the NSDE Sample and Procedures

Participants in the NSDE were recruited after having completed the second wave of the Midlife in the United States Survey (MIDUS II), a nationally representative sample of adults ranging in age from 35 to 84. A random subsample of 3,600 MIDUS II respondents were recruited to participate in the NSDE and a total of 2022 respondents completed the wave 2 daily NSDE interviews, a response rate of 78%. The NSDE subsample had very similar distributions to the MIDUS II for age as well as marital and parenting status. The NSDE subsample had slightly more females, were better educated, and had fewer minority respondents than the MIDUS II sample.

Respondents in the NSDE completed short telephone interviews about their daily experiences on each of eight consecutive evenings. On the final evening of interviewing, respondents also

answered several questions about their previous week. The initial and final interview last approximately 15–20 minutes. The other six interviews last approximately 10–15 minutes. The 2022 respondents completed an average of 7.4 out of a possible 8 interviews (92%) yielding 14,912 daily interviews.

Daily stressors were assessed through the Daily Inventory of Stressful Events (Almeida et al., 2002). This instrument generated several variables for each reported stressor including: (a) content classification of the stressor (e.g., work overload, argument over housework, traffic problem); (b) focus of who was involved in the event; (c) dimensions of threat (loss, danger, disappointment, frustration, opportunity); (d) objective and subjective severity of stressors; and (e) primary appraisal (i.e., areas of life that were at risk because of the stressor). Objective severity was based on normative unpleasantness and disruption as rated by expert coders (Brown & Harris, 1978), not the participants' evaluations of their stressors. Objective severity ratings were coded from respondents' descriptions of the stressors (e.g., how long did the stressor last and who was involved) rather than their affective response to these stressors. Coders also rated appraisals of danger and frustration. Subjective severity, on the other hand, was based on respondents' answers to questions about perceived severity.

Daily Saliva Collection and Cortisol Assaying

As part of recruitment, respondents received a Home Saliva Collection Kit one week prior to their initial phone call. Saliva was obtained using salivette collection devices (Sarstedt). Sixteen numbered and color-coded salivettes were included in the collection kit, each containing a small absorbent wad, about 3/4 of an inch long, as well a detailed instruction sheet. In addition to written instructions, telephone interviewers reviewed the collection procedures and answer any questions. Respondents provided 4 saliva samples per day on days 2 through 5 of the 8-day period to be assayed for cortisol. In order to maximize compliance, our collection procedures were designed to be as convenient as possible. On saliva collection days, respondents produced 4 saliva samples throughout the day, one upon awakening, one 30 minutes after getting out of bed, one before lunch, and one at bed time.

When all 16 tubes are ready to be sent, participants used a pre-addressed, paid courier package for the return mailing. The enclosed salivettes were shipped to the MIDUS Biological Core at the University of Wisconsin, where they were stored in an ultracold freezer at −60 °C. For analysis, the salivettes were thawed and centrifuged at 3000 rpm for 5 minutes yielding a clear fluid with low viscosity. Cortisol concentrations are quantified in singlet with a commercially available luminescence immunoassay (IBL, Hamburg, Germany), with intra-assay and inter-assay coefficients of variations below 5 percent (Dressendörfer, Kirschbaum, Rohde, Stahl, & Strasburger, 1992; Polk, Cohen, Doyle, Skoner, & Kirschbaum, 2005).

Salivary levels accurately reflect the unbound, biologically active, fraction of cortisol in general circulation (Granger & Kivlighan, 2003). Cortisol in saliva is very stable once collected and can be stored frozen for up to at least 2 years at 20° C without compromising sample integrity. The application of salivary markers in biobehavioral research must be conducted with care to ensure valid results. The literature warns that a variety of substances can raise or lower the pH of saliva (Granger at al., 2007; Kirschbaum, Read, & Hellhammer, 1992). Performance of salivary immunoassays becomes compromised as the pH of samples to be tested drops below 4 or exceeds 9. Some food substances contain animal products (i.e., bovine hormones in milk products) that cross-react with the antibodies used to estimate hormone levels in immunoassays. Increases in hormones in blood and saliva can be reliably detected following consumption of protein-rich major meals (Kirschbaum et al., 1992). It is also widely known that systemic infection (i.e., indicated by body temperature above 102° F) is associated with activation of the HPA-axis and subsequent cortisol increases (Kirschbaum et al., 1992).

The sample collection, handling, and assay procedures were designed to minimize the potential impact of the above factors on assessments of saliva biomarkers. The directions included in the Home Saliva Collection Kit clearly stated that sample collection is to occur at least 1 hour after consumption of a major meal. Prescription and over the counter medications taken during the collection period were recorded, as were a history of any endocrine-related disorders. Participants were also instructed to restrict milk intake or any dairy product for 20 minutes before each sample collection. Prior to immunoassay for cortisol, the sample's pH was checked and corrected if outside the acceptable range (pH 4–9). These home collection procedures have been successfully applied in dozens of studies, and these methods do not interfere with the assay (Granger & Kivlighan, 2003).

Challenges of Diary Studies

Conducting daily diary studies in large social surveys presents unique challenges due to the respondent burden and lack of investigator control in collecting biomarkers. The next section provides evidence of for the feasibility, reliability, and validity of daily diary assessment using the second wave of the NSDE.

Challenge 1: Feasibility regarding recruitment and retention

Given the requirements of the daily stress approach that involve daily interviews and multiple saliva collections throughout the day, a key issue is the feasibility of implementing this approach in a large social survey such as the Panel Study of Income Dynamics (PSID) in which the data are collected over the telephone and the age of participants spans the full life course. Findings from the telephone-based NSDE and other studies suggest that overall, respondents are willing to participate and complete the protocol. Seventy-eight percent of respondents from the parent MIDUS II study participated in the second wave of the NSDE and completed an impressive 94% of the nightly interviews. Furthermore, NSDE respondents did not substantively differ from the MIDUS II participants on major key demographic characteristics suggesting minimal problems with selection bias. Participants also overwhelmingly participated in the saliva collection protocol. Of the 2,022 respondents who completed the second wave of the NSDE, 1,736 provided saliva samples (86%). Perhaps more remarkable was the rarity of missed saliva collections -- less than 3%. This protocol has been adapted by other social surveys that include samples of elderly couples; mothers of children with autism; and hotel workers, their spouses, and children (O'Neill et al., 2009; Seltzer et al., 2009; Yorgason, Almeida, Neupert, Spiro, & Hoffman, 2006). Although the sample and protocol are somewhat different, the recruitment and retention rates are similar to the NSDE.

Thus, while there is promising evidence on the feasibility of implementing this approach in a large nationally representative survey such as the PSID, subsampling various individuals and/or dyads and/or entire families is an alternative strategy that may be consistent with particular research goals and budget constraints. Such targeted supplemental designs focus on particular subsamples within large ongoing social surveys like the PSID and others, including the Health and Retirement Study (HRS) and the British Household Panel Study (BHPS), for example, and may give added flexibility to the addition of the daily stress approach. For example, two recent PSID supplements are illustrative of potential subsampling platforms that could be used for the daily approach: the three-wave, mixed-mode PSID - Child Development Supplement (CDS) which collected time diary and other data both via telephone and in the home from children and caregivers to examine the interconnections of family, neighborhoods, and schools and their effects on child development; and the Disability and Time Use Supplement to PSID (DUST) which subsampled older married couples who varied in disability status to assess time use, disability, and well-being via telephone. These designs differed in participant characteristics and mode of data collection yet each could be readily modified to include the daily stress approach.

Challenge 2: Reliability

If respondents agree to participate in daily stress studies, will they be compliant? Adherence to the saliva collection protocol is critical in obtaining reliable assessments of diurnal cortisol. We gauged compliance by contaminated samples and timing of collection. Of the 27,776 possible saliva samples (1,736 × 16 samples), there were 874 missed samples, samples that could not be linked to a specific day, or samples with insufficient volume to detect cortisol (~ 3 percent). These data resulted in final cortisol analyses based on 97% usable samples (*N* = 26,902).

Data on the exact time respondents provide each saliva sample was obtained from the nightly telephone interviews and on a paper-pencil log sent with the collection kit. In addition approximately 25 percent of the respondents (N= 430) received a “Smart Box” to store their salivettes. These boxes contained a computer chip that recorded the time respondents opened and closed the box. The correlations of self-reported times across collection occasions were all above .9. The correlations between self-reported times and times obtained from the “smart box” ranged from .75 for the evening occasion to .95 for the morning occasion. Assessing diurnal rhythm also requires careful timing of collection. The biggest challenge we faced was collection of the second sample of the day (30 minutes after awaking). Missing this time window could alter the assessment of the cortisol awakening response (CAR) parameter of the diurnal rhythm. On approximately 10 percent of our collection days, respondents either provided the sample too early or too late to capture the CAR. Additional protocols could be implemented to increase adherence to this critical time window, including alarm clocks, electronic time stampers, and additional instructions. Indeed our team at Penn State recently produced an instructional video in collaboration with our local public television affiliate on how and when to collect saliva (a copy is available upon request to the senior author). Future data collections will include tests instructions on a DVD in the saliva collection kits.

Challenge 3: Validity

Lack of control over saliva collection in social surveys poses risks to the interpretation of cortisol. We used NSDE data to assess the validity of field assessments of diurnal cortisol. We compared components of the diurnal rhythm of cortisol in the NSDE with smaller samples in more controlled research settings and with more within-day assessments. The top rows of Table 1 compare our cortisol values for the cortisol awakening response (CAR) to the findings of four studies combined and presented by Wüst et al. (2000). Mean cortisol levels in these published studies are very similar to the NSDE for both awakening cortisol and for cortisol measured 30 minutes after awakening. The next rows in Table 1 compare the daily decline slopes from the NSDE with for four studies reviewed in Stone et al., 2001). It is important to note these previous studies had more control over the study protocol such as face to face instruction and telephone reminders for collection. Despite the differences between these four studies and NSDE in the number of participants, the number of saliva collections throughout the day, and the number of days assessed, values for the slopes are remarkably parallel.

Challenge 4: Costs

The average cost of the NSDE protocol was approximately $350 per respondent. The collection kits including salivettes, packaging materials, boxes, and postage costs $44. The cortisol assaying was conducted in Biological Psychology Laboratory at the Technical University of Dresden at a cost of approximately $96 ($6 per sample × 16 samples). The interviewing cost via Penn State Survey Research Center was approximately $160 per person ($20 per interview × 8 interviews). Finally the participants were given $50 as incentive to finish the protocol.

Promising Findings from the NSDE

Daily Stressor Exposure and Reactivity

Using the Daily Inventory of Stressful Events (DISE) NSDE respondents reported experiencing at least one stressful event on 39.4% of study days and multiple stressful events on 10.4% of study days (Almeida et al., 2002). Furthermore, there was a wide range of types of stressors respondents encountered. Although the most common stressors for both men and women were interpersonal arguments and tensions, accounting for half of all reported stressors, gender differences were evident. Women were more likely to report network stressors—stressors that happened within a network of relatives or close friends—and men were more likely to report paid work stressors, such as technical breakdowns, that were not interpersonal in nature. Respondents also provided information about the dimensions of the stressors that were threatening. Roughly 30% of the stressors involved some sort of loss, nearly 37% posed danger, and 27% implicated frustration. The most common type of perceived threat posed by daily stressors was a disruption to the respondent's daily routine as compared to the other domains of life (e.g., finances, health, and safety). Finally, respondents and objective coders rated stressor severity. On average, the respondents subjectively rated stressors as having medium severity, whereas objective coders rated the stressors as posing low severity (Almeida, Neiss, & Mroczek, 2006).

Previous work has shown that the DISE categories significantly predicted physical symptoms and psychological distress (Almeida, 2005). Multilevel models revealed that the entire set of DISE stressor variables accounted for 17% of the within-person variance in physical symptoms and 31% of the within-person variance in psychological distress (Almeida et al., 2002). Specific types of daily stressors, such as interpersonal and network stressors (i.e., events that occur to close others), were unique predictors of both physical symptoms and psychological distress. In addition, both investigator-rated threat and respondent-rated primary appraisal measures predicted physical symptoms and distress. Individuals who had a greater proportion of stressors that posed high severity, loss, or danger reported more symptoms and higher psychological distress. Furthermore, stressors appraised as disrupting daily routines or posing risk to physical health and safety were also shown to be unique predictors of symptoms and mood.

Linking Stressor Exposure to Diurnal Cortisol

The next examples describe links between aspects of daily stressors and daily fluctuations in cortisol. Adam and colleagues have shown that prior day feelings of loneliness and sadness were associated with higher cortisol awakening response (CAR) and that same day reports of tension and anger were associated with flatter decline slopes (Adam et al., 2006). Our preliminary work has extended these findings to examine associations between aspects of daily stressors and parameters of the diurnal rhythm of cortisol, including the slopes for the CAR and the daily decline (Cichy, Stawski, & Almeida, 2007). On days when individuals experienced more interpersonal tensions and more network events than usual as reported on the DISE, they had a more disrupted cortisol rhythm evidenced by a less steep decline in their cortisol. This disruption was even greater on days when individuals experienced interpersonal tensions involving family members. In general, overload stressors only resulted in a less steep decline in cortisol for individuals who experienced more overloads characterized by greater danger (i.e. risk of a future negative occurrence). These findings provide further evidence confirming the validity of self-reports of stressors assessing salivary cortisol in social surveys by linking naturally occurring stressful experiences with dysregulated cortisol rhythms.

Effect of Chronic Stress on Daily Stress Process

We have begun to assess how social structural factors, psychosocial characteristics, life challenges, and physical health predict diurnal cortisol. For example, we have examined the effect of nonnormative parenting, as a form of chronic stress, on daily stress processes (Seltzer et al., 2009). This was accomplished by comparing the daily lives of parents of adolescent and adult children with disabilities and parents of children who do not have such disabilities, using data from MIDUS and NSDE. Using daily telephone interviews, the parents of adolescent and adult children with disabilities (n = 82) were compared with a closely matched sample of unaffected parents (n = 82). We also examined whether parents of children with disabilities had dysregulated diurnal rhythms and the extent to which the amount of time spent with children was associated with divergent patterns of cortisol expression. We found that parents of children with disabilities had similar patterns of daily time use and a similar likelihood of positive daily events as the comparison group did, but they had elevated levels of stress, negative affect, and physical symptoms, all of which were reported on a daily basis. In addition, nonnormative parents' diurnal rhythm of cortisol differed significantly from the comparison group. Parents of children with disabilities exhibited a greater CAR and flatter daily slopes. Furthermore, the pattern for daily slopes was strongest for parents of children with disabilities on days when they spent more time with their children.

Daily Stress and Physical Health: Potential synergies

This line of inquiry has direct relevance to research on allostatic load. Allostatic load refers to accumulated wear and tear on the body—the result of constant physiological adjustments to physical and psychological stressors (McEwen & Stellar, 1993). Allostatic load is commonly measured by indicators of physiological reactivity and physiological dysregulation, such as cholesterol levels or blood clotting ability and has been found to predict cognitive and physical decline (McEwen & Stellar, 1993; Seeman, Singer, Rowe, Horwitz, & McEwen, 1997). Researchers have examined changes in allostatic load components in response to stressful events, such as alterations in immune functioning in response to relocations and medical exams (Kiecolt-Glaser et al., 1986) or correlations of immune function and/or cortisol levels with checklists of stressors, self-ratings of stressful jobs, and marital dissatisfaction (e.g., Bauer et al., 2000; Brosschot, Benschop, Godaert, & Oliff, 1994; Herbert & Cohen, 1993; Kiecolt-Glaser et al., 1986; Malarkey, Hall, Pearl, Kiecolt-Glaser, & Glaser, 1991). Ironically, researchers have conceptualized allostatic load as a physical vulnerability caused by chronic adjustments to repeated stressors of life, yet few studies have examined allostatic load in conjunction with daily accounts of stressors. With data from the other biomarkers (such as those recommended in other papers in this special issue), researchers could examine how patterns of daily stressors correlate with biological mechanisms. Specific indicators include both an overall allostatic load measure and discrete measures of metabolic function, immune markers, and global endocrine functioning.

Examining multiple daily stressors, personal characteristics, and other biological measures permit us to explore how specific types of stressors are related to physiological processes, and how these relations may vary according to dispositional and other individual difference factors. Some stressors may be more detrimental than others, for example Herbert and Cohen (1993) found that interpersonal stressors had a greater effect on immune reactions than other types of stressors.

Application of the Daily Stress Approach to Social Surveys

Specific features in ongoing social surveys such as the PSID, HRS, and others offer exciting opportunities for applying the daily stress approach described in this paper. These features include preexisting longitudinal data, large samples that are nationally representative, and

genealogically-based designs that include multiple family members. These features extend research on stress and mental health in several key areas.

Longitudinal Data

Panel data collected over a long period permit an examination of how preexisting circumstances are linked to daily stress exposure and reactivity. Prior research linking early life experiences to adult functioning has found evidence of connections between adverse living conditions and financial hardship in childhood, for example, on adult depression (e.g., Kessler and Magee, 1994; Springer, Sheridan, Kuo, & Carnes, 2007) and daily stress reactivity (Almeida & Horn, 2004); however these data have relied upon retrospective reports of early life. Data obtained over many waves can be used to tease out the pathways through which life course economic, social, and psychological factors affect the daily experience of stress exposure and reactivity. Using the full age course allows further specificity of life cycle variation in these relationships, as well as an exploration of economic and social factors that contribute to alterations in these pathways. Moreover, going forward in time, the effects of exposure and reactivity on future experiences can be examined. These features are particularly prominent in a long-lived panel like the PSID which has been collecting economic, socio-demographic, and health data from the same families and their descendants for more than four decades.

Repeated measurement of various domains on the same individuals over the life course, such as that collected by the PSID and other panel studies, allows important questions to be addressed. How do early life experiences shape adult stress exposure and reactivity? In particular, how does chronic stress such as poverty in childhood, low birth weight, or residing in a high-crime neighborhood affect exposure and reactivity later in life, net of current SES? What are mechanisms through which such effects might occur, such as a trajectory of low education, poor job, and resulting financial stresses? Importantly, what aspects of one's life circumstances may modify these relationships? Do many severe stressors early in life have additive or multiplicative effects on reactivity? How are such effects depend upon the characteristics of the life events themselves, in terms of content, severity, persistence, and timing? What aspects of life experience can reduce stressor exposure and reactivity, such as quality of interpersonal relationships, educational attainment, socioeconomic status, and health? And how does stress exposure and reactivity become a trajectory for the achievement process in the future, including SES and educational attainment?

A number of large social surveys have documented that individuals with lower levels of socioeconomic status (SES) are at increased risk for major stressful events and chronic difficulties (e.g., violence, discrimination) and are thus more likely to suffer distress (Dohrenwend, 1970, 1973; Marmot, Ryff, Bumpass, Shipley, & Marks, 1997; Myers, Lindenthal, Pepper, & Ostrander, 1972). One possible mechanism for this association is the finding that lower SES individuals are more emotionally vulnerable to major stressor events (Brown & Harris, 1978; Kessler & Cleary, 1980). More recent work shows that this is true for day-to-day stressors as well (Almeida, Neupert, Banks, & Serido, 2005; Grzywacz, Almeida, Neupert, & Ettner, 2004). Alternatively, the sheer number of stressors to which socioeconomically disadvantaged individuals are exposed (combined with a dearth of resources to combat these stressors) may increase their vulnerability (Grzywacz, et al., 2004).

Large nationally representative samples such as those found in studies like the PSID also allow for important subgroup analyses. For example stressor exposure and reactivity can be studied for major racial and ethnic subgroups. How does the “stressor exposure profile” of young African Americans look compared to young White Americans, for example? These data about age and race heterogeneity in the daily stress process can shed light on trajectories that lead to future health and economic outcomes such as affective functioning and educational attainment,

for example. Nationally representative, full life course data could be used to generate an index of daily stressor exposure among U.S. families by major socio-demographic groups.

Genealogical Sample Design

Studies with genealogical sample designs including the PSID and the British Household Panel Study support a range of powerful intra- and intergenerational analysis. The literature on daily stress documents a process of familial stress contagion (Hammer, Allen, & Grigsby, 1997; Larson & Almeida, 1999; Repetti, Taylor, & Seeman, 2002) which can be studied robustly with related families. Recent work provides some fascinating insights into how stress spills over between family members. For example, aspects of parents' level of stress such as marital functioning (Pendry & Adam, 2007) and maternal depression (Ashman, Dawson, Panagiotides, Yamada, & Wilkinson, 2002) have been linked to elevated cortisol levels in children. Future studies could ask if specific stressors that parents experience (e.g., work demands and interpersonal tenstions) elevate cortisol levels in children. Genealogical data can be used to examine such familial dynamics in stress contagion with large, representative samples. For example, within co-resident family members, how is stressor exposure and reactivity transmitted from parents to children, as well as between spouses and siblings? And how do life circumstances such as SES, education, and race affect such transmission?

Data from multiple generations of family members opens up opportunities for the study of the transmission of stress between generations. What is the intergenerational correlation in stressor exposure and reactivity? Are parents and their adult children exposed to similar types, levels, severity of daily stress even when they are not co-resident? If so, why? Do related parents and children – and grandparents and children – exhibit similar stressor reactivity as assessed by cortisol? That is, is stress reactivity genetically influenced?

Ethical Concerns

Integration of salivary biomarkers, particularly cortisol, into social science research has grown increasingly popular (Kirschbaum et al., 1992). Home collection of saliva samples by study participants is relatively non-invasive, simple, and fast (Granger et al., 2007). For some individuals (e.g., the oldest-old) and under particular conditions, however, there may be issues with specimen collection such as insufficient volume for assay, time burden, and increased difficulty with the protocol (Granger et al., 2007). Other concerns revolve around participant worries regarding the use of saliva for drug testing or assessing genetic markers.

Participants should be aware of how their saliva will be used currently and in the future. It is critical to maintain confidentiality and obtain consent for examination of biological material as well as storage of saliva. Specimens could be quickly and properly disposed of following study completion in order to address concerns associated with long-term storage. Assigning participants a unique identifying number to appear on all saliva collection materials, with the code link connecting ID numbers and names available only to principal investigators and research assistants, aids in ensuring confidentiality.

Conclusion

The application of a daily stress approach to assess mental health in large longitudinal social surveys offers a unique opportunity to include physiologic measures of ongoing adaptation to complement self-report data. While there are operational challenges associated with the collection of diurnal salivary cortisol in the field, these challenges are largely known and experience from other survey-based data collections demonstrates that such an approach is feasible for a large national panel study like the PSID. Particular data collection designs may also be scientifically and budgetarily advantageous, including sampling subgroups of

individuals and family members who may experience stressors unique to particular life stages (e.g., older ages, caregiver status), ongoing health conditions, or other major life events or persistent circumstances such as financial stress. The demographic heterogeneity of a large nationally representative social survey also lends itself to comparative analyses of stressor exposure and reactivity between many socio-demographic groups which will help us define the trajectories that lead to disparities in future health and economic outcomes, In sum, the collection of daily data on stressor exposure and reactivity in a long panel such as the PSID would generate high scientific value in understanding naturally occurring stress processes in US families.

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Table 1

Comparison Table of Diurnal Cortisol Parameters from NSDE with other Salivary Cortisol Studies

	N	Number of Days	Wake (Mean)	Wake (*SD*)	30 Minute (Mean)	30 Minute (*SD*)
Morning Samples[a]						
Wüst et al. (2000)	509	2	15.12	6.3	22.95	9.1
NSDE	1,736	4	15.21	5.9	21.22	7.7
	N	Number per Day	Slope (Mean)		Slope (*SD*)	
Daily Decline Slope[b]						
Kirschbaum (1999)	66	25 × 1	−.11		.04	
Kirschbaum (1994)	20	49 × 2	−.11		.04	
Cohen (2001)	176	9 × 2	−.10		.04	
Smyth (1999)	39	3 × 24	−.09		.06	
NSDE	1,736	3 × 4	−.11		.03	

[a] Measured in nmol/l.

[b] Calculation of slope was similar across all five studies, using multilevel modeling where each person's cortisol data were regressed against time of day.