Psychology and Aging
2009, Vol. 24, No. 4, 828–840

0882-7974/09/$12.00 DOI: 10.1037/a0017925

Intraindividual Change and Variability in Daily Stress Processes: Findings From Two Measurement-Burst Diary Studies

Martin J. Sliwinski and David M. Almeida
Pennsylvania State University

Joshua Smyth
Syracuse University

Robert S. Stawski
Pennsylvania State University

There is little longitudinal information on aging-related changes in emotional responses to negative events. In the present article, we examined intraindividual change and variability in the within-person coupling of daily stress and negative affect using data from 2 measurement-burst daily diary studies. Three main findings emerged. First, average reactivity to daily stress increased longitudinally, and this increase was evident across most of the adult lifespan. Second, individual differences in emotional reactivity to daily stress exhibited long-term temporal stability, but this stability was greatest in midlife and decreased in old age. Third, reactivity to daily stress varied reliably within-persons (across-time), with individuals exhibiting higher levels of reactivity during times when reporting high levels of global subject stress in the previous month. Taken together, the present results emphasize the importance of modeling dynamic psychosocial and aging processes that operate across different time scales for understanding age-related changes in daily stress processes.

Keywords: longitudinal change, aging, stress, emotion, health

Efforts to understand the impact of psychosocial stressors have increasingly focused on the role of minor events or daily hassles. Daily stressors exhibit immediate effects on emotional and physical functioning on the day they occur (e.g., Bolger & Schilling, 1991; Zautra, Affleck, Tennen, Reich, & Davis, 2005) and create aggregated effects that increase vulnerability to problems, including anxiety, depression, and disease (e.g., Almeida, 2005; Cacioppo et al., 1998; Lazarus, 1999; Zautra, 2003). Because both resources of individuals and their environments limit or enhance the possibilities and choices for coping with daily experiences, reactivity to stressors is likely to differ across people as well as across situations. Given aging-related changes in personal resources and environments, one might expect concurrent changes in daily stress processes, particularly in terms of emotional responses to daily stressors.

Daily stressors are events that an individual appraises as presenting a challenge, threat, or potential loss, such as interpersonal tensions and excessive demands at work or home. The term reactivity implies that within-person changes in mood states result from experiencing proximal antecedent stressors. Quantifying the amount by which negative affect (NA) increases on high stress days compared with low stress days provides one way to approximate reactivity to daily stress. Accordingly, we operationally define reactivity to daily stress as the covariation or "coupling" between stress and affect (Bolger & Schilling, 1991; Zautra et al., 2005). Previous research has examined cross-sectional age differences in the coupling of daily stress and affect (Mroczek & Almeida, 2004; Stawski, Sliwinski, Almeida, & Smyth, 2008), but there is limited data on longitudinal changes in this relationship.

In this article, our objective is to examine intraindividual variability and change in the daily stress–NA relationship using data from two longitudinal measurement-burst studies. Measurement-burst designs consist of repeated sequences of daily measurements (Nesselroade, 1991; Sliwinski, 2008). The first study, the National Study of Daily Experiences (NSDE), obtained a burst of daily measurements in a sample adults (mean age = 47 years), which was repeated in the same sample after a 10-year interval. The second study—the Cognition, Health, and Aging Project (CHAP)—obtained repeated bursts of daily measurements in a sample of older adults (mean age = 80 years) every 6 months for a period of 2 years. Integrating analyses of these two studies permits characterization of intraindividual variability and change in daily stress processes across short (6-month) and long (10-year) temporal intervals, as well as across a very broad segment of the adult lifespan.

Martin J. Sliwinski, David M. Almeida, and Robert S. Stawski, Department of Human Development and Family Studies, and The Gerontology Center, Pennsylvania State University; Joshua Smyth, Department of Psychology and Center for Health and Behavior, Syracuse University.

The Cognition, Health, and Aging Project was supported by National Institutes of Health (NIH) Grants R01 AG12448 and AG026728. The National Study of Daily Experiences was supported by NIH Grants P01 AG0210166-02, R01 AG19239, T32 MH018904, and the Network on Successful Mid-Life Development of the John D. and Catherine T. MacArthur Foundation. These analyses were supported in part by the Integrative Analysis of Longitudinal Studies of Aging research network funded by NIH Grant R01 AG026453.

Correspondence concerning this article should be addressed to Martin J. Sliwinski, The Gerontology Center, Pennsylvania State University, University Park, PA 16802. E-mail: mjs56@psu.edu

Age Changes in Daily Stress and NA

The literature on emotional development in adulthood suggests that older adults are both motivated and capable of regulating NA. For example, socioemotional selectivity theory (SST; Carstensen, 1995) postulates that older adults perceive limited time left in life, which increases motivation to select environments that optimize emotional functioning. However, the relevance of SST for making predictions regarding emotional responses to stressors is complicated. For example, Carstensen, Pasupathi, Mayr, and Nesselroade (2000) stated the following: "once negative emotions are elicited, the theory makes no claims about the intensity of the experience" (p. 645), implying that SST does not predict either an age-related increase or decrease in the emotional response elicited by exposure to stressors. Yet, the intensity of emotional experiences has sometimes been examined in the context of SST (Charles & Piazza, 2007).

Nonetheless, the general notion that emotion regulation skill improves with age leads to the expectation of decreased negative emotional responses to daily life stressors. For example, increased motivation to optimize emotional function coupled with knowledge, resources, and understanding accumulated from prior experiences should enable older adults to more easily adapt to everyday stressful situations (Whitbourne, 1985, 1986). Consistent with this view, older adults report better emotional control skills (Gross et al., 1997; Lawton, Kleban, Rajagopal, & Dean, 1992), fewer negative experiences, shorter durations of negative mood (Carstensen et al., 2000), and less of an increase in negative mood during daily stress compared with younger adults (Uchino, Berg, Smith, Pearce, & Skinner, 2006).

However, other studies have shown larger increases in NA in older adults who view stressors in a negative light (Mroczek & Almeida, 2004; Mroczek, Spiro, Griffin, & Neupert, 2006) or who have recently experienced high levels of subjective stress (Stawski et al., 2008). Despite being motivated to optimize emotional experiences, objective environmental demands, diminished personal resources, and the cumulative burden of negative life events may render older adults more emotionally reactive to stressful situations. Repeated stress exposure across the lifespan may represent another pathway by which age-related increases in stress reactivity could occur. This heightened reactivity may be akin to kindling effects, a process in which repeated exposure to some stimulus causes sensitization (Kendler, Thornton, & Gardner, 2001; van der Kolk, 1997; Woolf & Costigan, 1999). Consistent with this view, Uchino and colleagues have shown increased cardiovascular reactivity to daily stress in older adults (Uchino et al., 2006) as well as significant longitudinal increases in cardiovascular reactivity to an experimental stressor (Uchino, Holt-Lundstad, Bloor, & Campo, 2005).

Everyday psychosocial stressors can activate cardiovascular, endocrine, and immune responses (e.g., Stone, Marco, Cruise, Cox, & Neale, 1996; van Eck, Berkhof, Nicolson, & Sulon, 1996), which could play a role in the onset of illnesses. Some researchers have hypothesized that these physiological responses are mediated by emotional responses to stress (e.g., Cohen et al., 2000; van Eck, Nicolson, & Berkhof, 1998). Mood states, which are more negative on days with more frequent or severe stressful events (e.g., Bolger & Zuckerman, 1995; Cacioppo et al., 1998; van Eck et al., 1998), are often used to characterize how individuals react to everyday stressors. Thus, studying age changes in stress-related affect may prove important for understanding age-related changes in health and disease risk.

Inter- and Intraindividual Variability in Reactivity

Individuals vary in their emotional responses to daily stressors according to personality traits, such as neuroticism (Bolger & Schilling, 1991; Bolger & Zuckerman, 1995; Mroczek & Almeida, 2004) and trait anxiety (van Eck et al., 1998). Examining predictors of individual differences in reactivity presupposes that reactivity itself exhibits trait-like stability. Indeed, Cohen et al. (2000) stated that "the concept of stress reactivity refers to a stable individual difference in response to stressors" (p. 171). A number of studies have provided evidence of a stable cardiovascular response to stress over a 2-week interval (test–retest correlations = .50–.67) and over a 1-year interval (Uchino et al., 2005; test–retest correlations = .22–.75). There is also evidence of stable emotional reactivity, with a 2-week retest correlation of .64 for stress-induced increases in anxiety (Cohen et al., 2000). The degree to which these test–retest analyses support the notion that reactivity is a trait depends on whether one takes a "glass is half-empty" or "half-full" perspective. As regards emotional reactivity, a 2-week retest correlation of .64 is high, but it also implies that less than two thirds of the variability is stable, even over a very short interval—the remaining third may reflect measurement error or meaningful within-person across-time variability in reactivity. It is possible that reactivity varies reliably not only between individuals but also within individuals across time; however, studies typically do not examine this possibility, instead treating reactivity as a fixed (invariant) characteristic of the person.

Reactivity may change within persons across relatively long time periods, reflecting the influence of aging processes. For example, diminished coping resources and resilience that accompany advancing age may bring about increases in average levels of emotional reactivity to daily stressors. This process may evolve slowly and therefore manifest only across relatively long time periods (e.g., years). Reactivity may also fluctuate more rapidly across brief time periods or "epochs," such that an individual may be more reactive during one time period than another. This second type of process may reflect a person's health status and psychosocial contexts (e.g., available social support, external demands) that are relatively constant during a given brief temporal epoch (e.g., a given week) but may vary considerably across longer intervals (e.g., months). An important goal of this article is to distinguish among stable between-person differences, long-term intraindividual changes, and shorter term intraindividual variability in reactivity. These effects may reflect the influence of relatively stable personality processes (e.g., trait neuroticism), slow-changing aging processes (e.g., diminishing cognitive resources), and more fast-changing dynamic psychosocial processes (e.g., operant burden), respectively.

Modeling Intraindividual Variability in the Stress–Affect Relationship

For the present study, we operationalize emotional reactivity to daily stressors as the amount by which an individual's NA increases on high compared with low stress days. Thus, reactivity reflects the within-person relationship between affect and stress. It is important to note that the design of the present studies precludes establishing a temporal relationship between stressful events and emotional states necessary to demonstrate reactivity. Such a relationship unfolds across minutes and cannot be effectively probed using daily assessments without encountering problems of recall bias and accuracy. Consequently, our use of the term *reactivity* assumes, without demonstration, that end of day reports of negative emotions are influenced by previously encountered stressful events.

Figure 1 (Burst 1) displays such a relationship for three hypothetical individuals, with Person 1 displaying the most reactivity (steepest slope) and Person 3 displaying the least (shallowest slope). When researchers try to identify variables that can account for variability in within-person processes, such as reactivity to minor daily events, their focus is often on how between-person variables (e.g., personality, disease group, gender) can predict between-persons differences in reactivity. However, a given individual may be more emotionally reactive at some times compared with other times in addition to being more or less reactive, on average, than other persons.

Suppose that the data in Figure 1 came from "bursts" of daily assessments that were repeated three times at 6-month intervals (depicted in the Burst 2–Burst 4 columns). The variability of slopes across rows (persons) reflects "stable" individual differences in reactivity, whereas variability of slopes across columns (bursts) in any given row (person) reflects intraindividual variability in reactivity. The deviations of individual data points from their regression lines convey measurement error. Thus, there are two critical sources of variation related to reactivity that require explanation: (a) stable individual differences in reactivity that persist across time and (b) within-person variability in reactivity across time (Sliwinski, 2008). Analyses of measurement-burst data can distinguish stable variance in reactivity from variance that reflects within-person fluctuations in reactivity.

Different variables might account for between-person and within-person variability in reactivity to daily events. For example, trait neuroticism might explain between-person variability, whereas recent exposure to negative life events or chronic difficulties might be a stronger predictor of why a given individual is more reactive at some times compared with other times. There is a strong empirical and conceptual basis for examining neuroticism as a moderator of reactivity to daily stressors. First, individuals high in trait neuroticism tend to experience stressful events as more aversive and react with higher levels of NA than do those with lower levels of the trait (e.g., Bolger & Schilling, 1991; Bolger & Zuckerman, 1995; Mroczek & Almeida, 2004). Second, during the appraisal process, individuals high in neuroticism are more likely to appraise events as threats rather than challenges (Lazarus & Folkman, 1984) and to focus on negative aspects of stressful experiences, increasing the likelihood of a negative emotional response. We examined whether stable individual differences in neuroticism moderated longitudinal changes reactivity in the NSDE sample.

Global perceived stress has been hypothesized to reflect a common pathway through which diverse individual differences characteristics may moderate the effects of daily events on mood. The Perceived Stress Scale (PSS; Cohen, Kamarck, & Mermelstein, 1983) is a commonly used instrument to measure global perceived stress, and it reflects the extent to which a person feels able or unable to deal with life's current demands. Individuals who report higher levels of global perceived stress exhibit higher levels of emotional reactivity to daily stressors (Stawski et al., 2008; van Eck et al., 1998). This relationship might reflect stable differences between those who score high and those who score low on the PSS. Scores on the PSS may reflect general tendencies in individuals to experience negative emotional states, but they also reflect the degree to which one's life is currently appraised as stressful. Thus, the PSS may be sensitive to dynamic influences, such as operant burden (H. Turner & Turner, 2005; R. J. Turner, Wheaton,

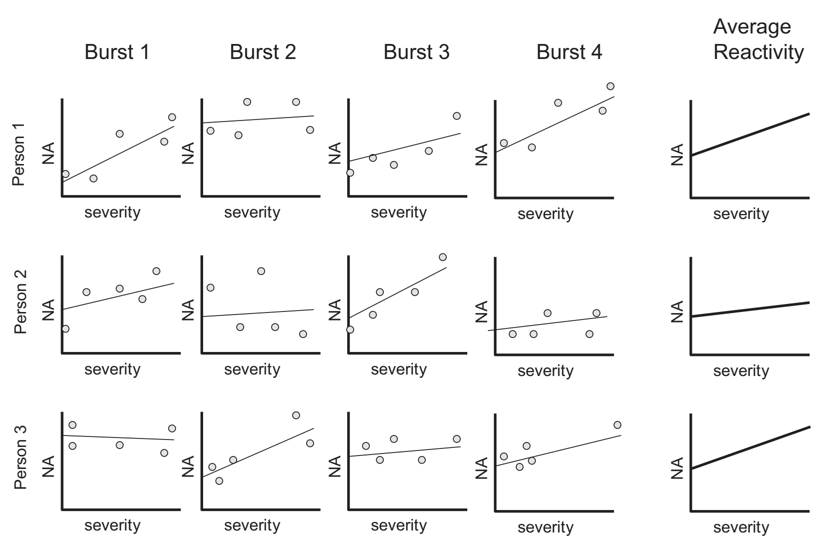

Figure 1. Within-person and between-person variability in daily stress reactivity slopes depicted in a hypothetical measurement-burst design. Variability in slopes across columns (Bursts 1–4) depicts within-person variability in daily reactivity, whereas variability across rows (in average reactivity) depicts between-person variability in daily reactivity. NA = negative affect.

& Lloyd, 1995) as well as changes in the availability of coping resources. Cohen et al. (1983) noted the state-like characteristics of the PSS by contrasting its relatively high retest correlation of .85 when administered 2 days apart with a lower stability coefficient (.55) when administered 6 weeks apart. Global perceived stress is not a state variable like mood in the sense that it varies considerably from moment to moment (or even from day to day), but it is a "slow-state" variable in the sense that it is exhibits marked variability across weeks or months. Thus, it is possible that the relationship between global perceived stress and reactivity to daily events might reflect the interaction of two dynamic processes that operate over very different temporal intervals, one being global stress that fluctuates rather slowly (across weeks or months) and the other being emotional reactivity, which reflects a concurrent relationship between daily events and mood.

Hypotheses and Integrative Analyses Across CHAP and NSDE Data Sets

In the present article, we address three main questions regarding age changes in emotional reactivity to daily stress. First, we address the question of whether the stress–NA relationship tends to increase or decrease in magnitude with advancing age. We use data from the NSDE (mean age = 47 years at baseline) to examine these changes through young adulthood and midlife. The sample is older in CHAP (mean age = 80 years at baseline), which extends our analyses of intraindividual changes into old age. Second, we examine how much long-term stability in individual differences that emotional reactivity exhibits. The repeated bursts for the NSDE were 10 years apart, making these data suitable for describing long-term age changes as well as for estimating very long-term stability in reactivity to daily stress. The presence of long-term stability would provide evidence for the trait-like characteristics of emotional reactivity to daily stressors. Third, we use CHAP data to determine whether there is reliable within-person variability in emotional reactivity to daily stress across 6-month intervals. We also examine whether within-person variations in global perceived stress are coupled with within-person variations in reactivity across measurement bursts. That is, we examine whether the magnitude of daily stress with NA within-person relationship is itself coupled with within-person fluctuations in global perceived stress across longer time intervals.

Method

NSDE Sample

Participants in the NSDE were recruited after having completed the first wave of the Midlife in the United States Survey (MIDUS). The MIDUS is a national sample of adults ranging in age from 25 to 74 years. Of the original 3,032 MIDUS survey participants, 1,012 completed the first wave of the NSDE, which occurred between 1996 and 1997—671 of whom were reassessed approximately 10 years later for the second waves of MIDUS and NSDE data collections. It should be noted that data collection for the second wave of the NSDE is still underway, so the current study is based on the available longitudinal sample. Thus, the sample for the current study was composed of 671 adults who ranged in age from 24 to 75 years at baseline (M = 47, SD = 12). Of the sample, 58% were female, and the sample was fairly well educated—with 17% having obtained education beyond a 4-year degree, 50% having obtained either a high school diploma or 4-year degree, and 33% having obtained less than a high school diploma. Of the participants, 94% were White, 3% were African American, and 3% belonged to other racial groups.

NSDE Measures

Affect. The items consisted of four items from the K6 Non-Specific Psychological Distress Scale (Kessler et al., 1994). The scale was developed from the following instruments: The Affect Balance Scale (Bradburn, 1969), the University of Michigan's Composite International Diagnostic Interview (Kessler et al., 1994), the Manifest Anxiety Scale (Taylor, 1953), and the Center for Epidemiological Studies Depression Scale (Radloff, 1977). Participants indicated how they felt during the previous 24 hr by making responses on a 5-point scale (0 = *none of the time*, 1 = *a little of the time*, 2 = *some of the time*, 3 = *most of the time*, 4 = *all of the time*). The items included the following: restless or fidgety, so sad that nothing could cheer you up, that everything was an effort, and hopeless. A total score for NA was obtained by summing across the items. Cronbach's alpha was .81 for the NA scale.

Daily stressors. We assessed daily stressors using the Daily Inventory of Stressful Events (DISE; Almeida, Wethington, & Kessler, 2002). We analyzed data from five stem questions asking whether certain types of daily stressors had occurred in the past 24 hr, representing interpersonal tensions (i.e., "Did you have an argument or disagreement with anyone since [this time/we spoke] yesterday?"; Did anything happen that you could have argued about but you decided to let pass in order to avoid a disagreement?"), work-related overloads (i.e., "Did anything happen at work or school that most people would consider stressful?"), home-related overloads (i.e., "Did anything happen at home that most people would consider stressful?"), and network stressors (i.e., "Did anything happen to a close friend or relative that turned out to be stressful for you?"). Subjective severity for each event was rated on a 4-point scale (0 = *not at all*, 1 = *not very*, 2 = *somewhat*, 3 = *very*). Individuals are then probed regarding the specific content of experienced stressors. However, for these analyses, we relied on subjective appraisals of stressor severity by calculating a total daily stress by summing the severity scores across all stressors for each day.

Neuroticism. We measured trait neuroticism using a four-item measure developed for the MIDUS study (Lachman & Weaver, 1997). Using a 4-point scale (0 = *not at all*, 3 = *a lot*), participants indicated how well, in general, the items (moody, worrying, nervous, and calm) described them. A neuroticism score was derived by taking the average rating across the four items. Cronbach's alpha for the current study was .74.

NSDE Procedure

The initial wave of NSDE data collection spanned an entire year (from March 1996 to March 1997) and consisted of 40 separate "flights" of interviews. Approximately 38 participants were assessed during each flight, and each flight consisted of short telephone interviews about participants' daily experiences conducted on eight consecutive evenings. The first interview was staggered across the day of the week to control for the possible confounding between day of study and day of week. The second burst of daily assessments occurred approximately 10 years after completion of the first burst. For the current sample, of the 10,736 possible interviews days (671 participants × 8 days × 2 waves), we had useable diary data for 10,273 of the days (95.6%). Neuroticism was obtained as part of the MIDUS survey, which preceded the NSDE data collection.

CHAP Sample

One-hundred-sixteen older adults were recruited for participation in a longitudinal study of health and cognition by advertising in local newspapers and flyers posted in senior centers. The average age at baseline was 80.23 (SD = 6.30, range = 66–95) and consisted of a higher percentage of women than men (72% vs. 28%, respectively). The average years of education was 14.9 (SD = 2.40). Of the participants, 97% were White, 2% were African American, and 1% was Asian. The retention rates were as follows: 78% (n = 90) completed all five bursts, 87% (n = 101) completed at least four bursts, 88% (n = 102) completed three or more bursts, and 93% (n = 108) completed at least one follow-up burst. Of the 26 individuals who missed at least one burst, eight died prior to their next burst, eight dropped out because of significant illness, six canceled appointments because of illness, two canceled appointments because of scheduling conflict, and two individuals moved out of state.

CHAP Measures

Affect. We measured negative affect using a five-item adjective checklist (Lawton, Kleban, Dean, Rajagopal, & Parmelee, 1992). Participants had to rate on a 5-point scale (0 = *not at all*, 1 = *a little*, 2 = *moderately*, 3 = *quite a bit*, 4 = *extremely*) whether they currently felt irritated, depressed, worried, annoyed, or sad. An NA total score was obtained by summing the ratings across all items. Cronbach's alpha was .85 for the NA scale.

Daily stressors. We assessed daily stressors using a variant of the DISE (Almeida et al., 2002). The version of the DISE included in this study consisted of five stem questions: During the past 24 hr, (a) Did you have an argument or disagreement with anyone? (b) Did anything else happen that you could have argued or disagreed about, but you decided to let it pass? (c) Did anything happen to a close friend or relative that turned out to be stressful for you? (d) Did anything stressful happen regarding your personal health? (e) Did anything else happen that most people would consider stressful?

For these stressors, participants rated the severity of each, using a 4-point scale (0 = *not at all*, 1 = *a little*, 2 = *somewhat*, 3 = *very*). Individual are then probed regarding the specific content of experienced stressors. However, for these analyses, we relied on subjective appraisals of stressor severity by calculating a total daily stress by summing the severity scores across all stressors for each day.

Global perceived stress (GPS). We measured GPS using Cohen et al.'s (1983) PSS. The PSS consists of 14 items asking how often the individual had felt over the past month and is considered a valid measure of general appraisals of how demanding or overburdened one's life is. Example items include the following: "In the last month, how often have you felt difficulties piling up so high that you could not overcome them?" and "In the last month, how often have you been able to control irritations in your life?" Items were rated on a 5-point Likert scale (1 = *never*, 2 = *almost never*, 3 = *sometimes*, 4 = *fairly often*, 5 = *very often*), with positive items being reverse coded and a total score obtained by summing all 14 items. As the reporting interval for this question was 1 month, it was asked only once at the beginning of each burst. Cronbach's alpha was .81.

CHAP Procedure

Participants were given a brief introduction to the study, and the experimenter obtained informed consent as approved by the Syracuse University Institutional Review Board. Participants were told that they were participating in a study examining health and cognition in adulthood. Participants were scheduled to visit the research site six times within a 12-day period. These bursts of daily measurements were repeated every 6 months for a 2-year period, yielding up to five bursts and 30 daily assessments.

Statistical Model and Analytic Approach

We used multilevel linear modeling (Raudenbush & Bryke, 2002) to analyze change and variability in stress-related NA. Data from both measurement-burst studies consist of daily observations nested within bursts and bursts nested within persons. We refer to these three levels as the *day level*, *burst level*, and *person level*, respectively. Partitioning variability into these three levels allows estimation of the relationship between NA and daily stress at each level. The following three-level, multilevel model was used to estimate the day-level (Level 1), burst-level (Level 2) and person-level (Level 3) relationships between daily stress severity ratings and NA:

$$\begin{aligned} na_{ijk} = {} & \beta_0 + \beta_1(stress\_day_{ijk}) + \beta_2(stress\_burst_{jk}) \\ & + \beta_3(stress\_person_k) + \beta_4(burst_{jk}) + \beta_5(stress\_day_{ijk} \\ & \times burst_{jk}) + \beta_6(stress\_burst_{jk} \times burst_{jk}) \\ & + \beta_7(stress\_person_k \times burst_{jk}) + e_{ijk} \\ & + v_{0jk} + v_{1jk}(stress\_day_{ijk}) + u_{0k} + u_{1k}(stress\_day_{ijk}) \\ & + u_{2k}(stress\_burst_{jk}) + u_{4k}(burst_{jk}) \end{aligned} \tag{1}$$

where NA_{ijk} is the NA score for day i, burst j, and person k. The $\text{stress\_day}_{\text{ijk}}$ variable refers to the self-reported stress severity for day i during burst j for person k. The $\text{stress\_burst}_{\text{jk}}$ variable refers to the average stress severity for person k during burst j, and the $\text{stress\_person}_{\text{k}}$ variable represents the average stress severity for person k aggregated across all days and bursts. The burst variable was centered at burst = 1, and the stress variables were grand-mean centered but were not further centered within-persons or within-bursts. One approach to separating the stress–NA relationships across the three levels of analysis would have used within-burst and within-person centering of the stress_day and stress_burst variables, respectively. However, this approach would imply that it is the level of stress relative to a person's average stress (or to the person's average stress for a given burst) that predicts NA, rather than the absolute level of stress. For example, within-person centering implies that a daily stress score of 0 (i.e., no stress on a particular day) has a different meaning for persons (and bursts) with different average levels of stress (Snidjers & Bosker, 1999). We chose to use the grand-mean centered raw stress values to maintain a consistent meaning of the daily stress values across individuals and bursts. This approach to centering results in the following interpretation of the stress regression coefficients: β1 is the average within-person day-level stress slope, β2 is the difference between the within-person day-level and within-person burst-level slopes, and β3 is the difference between the within-person burst-level and the (between-person) person-level slopes (Snidjers & Bosker, 1999). We used the ESTIMATE command from SAS PROC MIXED to produce burst-level (β1 + β2) and person-level (β1 + β2 + β3) reactivity slope estimates and their standard errors. The β4 coefficient reflects the average change in NA across bursts (i.e., the burst slope). The β5 coefficient reflects how much the day-level stress effect changes across bursts, and the coefficients β6 and β7 represent the interaction of burst with the burst-level and person-level stress variables, respectively.

The random effects in Equation 1 reflect variability across the three levels of analysis. The Level 1 residual, e_{ijk}, reflects the day-to-day variability of NA within bursts and persons. At Level 2, the random intercept, v_{0jk}, and a random slope, v_{1jk}, allows for the possibility that an individual may randomly vary in his or her level of NA (i.e., his/her intercept) and reactivity to daily stress (day-level stress slope) from one burst to the next. The Level 3 random effects allow for variability across individuals or between-person differences in intercept (u_{0k}), the day-level stress slope (u_{1k}), the burst-level stress slope (u_{2k}), and the burst slope (u_{4k}). Both the day-level and burst-level convey information about variability that transpires within individuals across time but at very different cadences.

In both CHAP and NSDE, the day-level reflects within-person variability that transpires across days. In the CHAP data, the burst-level reflects within-person variability and change across biannual assessments, and in the NSDE data, the burst-level reflects within-person change across a 10-year period. The person-level reflects time-averaged between-person differences across days and bursts that persisted across 2 years of follow-up in the CHAP data and 10 years of follow-up in the NSDE data.

Results

Is There Significant Intraindividual Change in the Stress–NA Relationship?

NSDE sample. Descriptive statistics and simple correlations for age, stress severity, NA, and neuroticism are provided in Table 1. As a first step, a multilevel model (MLM) was fit to the NSDE data that included effects for assessment day (to model daily trends in NA within bursts), burst (to model 10-year changes in average daily NA), baseline and age, and a Burst × Age interaction. Results from Table 2 (Model A) reveal a small but significant trend for assessment day, indicating a slight within-burst decrease in NA across the 8-day sampling period. Baseline age showed a small but significant negative association with NA (*estimate* = −0.01, $p < .01$), but burst showed a significant increase in NA (*estimate* = 0.09, $p < .01$) across the 10-year follow-up. The Burst × Age interaction was significant ($p < .05$), indicating more rapid increases in NA for older individuals.

Next, a version of the MLM described in Equation 1 was fit that included day-level, burst-level, and person-level stress effects. Because there were only two measurements bursts, the variance component reflecting within-person variability in reactivity daily stress (Var[v_{1jk}]) was constrained to 0, as was the variance for the burst-level stress slope (Var[u_{2k}]). Results in Table 1 (Model B) show that severity of daily stress was associated with increased NA within individuals across days (*estimate* = 0.14, $p < .01$), within individuals across bursts (*estimate* = 0.42, $p < .01$), and between individuals (*estimate* = 0.32, $p < .01$). The critical test involved the interaction between burst and the daily stress effect, which was both positive and significant (*estimate* = 0.04, $p < .01$), indicating that the within-person slope relating daily NA to stress severity increased in magnitude across the 10-year follow-up period. The Person-Level Stress × Burst interaction did not approach statistical significance, and the interaction of baseline age with any of the stress variables did not approach statistical significance. There was no interaction between the effect of assessment day and daily stress, indicating that reactivity was not increasing merely as a function of the number of assessments.

CHAP sample. Descriptive statistics and simple correlations for age, stress severity, NA, and global perceived stress are reported in Table 3. In Table 4, we reports analyses of the CHAP data that parallel

Table 1
Descriptive Statistics for the NSDE Sample

		Between-person correlations				
Burst	Variable	1	2	3	*M*	*SD*
1	1. Age	—			47.34	12.48
	2. Average stressor severity	−.17	—		2.16	1.07
	3. Average daily NA	−.18	.33	—	0.84	1.14
	4. Neuroticism	−.23	.22	.32	2.04	0.59
2	1. Age	—			56.49	12.46
	2. Average stressor severity	−.21	—		2.05	0.95
	3. Average daily NA	−.12	.33	—	0.92	1.28
	4. Neuroticism	−.23	.20	.33	2.02	0.61

Note. $N = 671$; $p < .01$ for all correlations. NSDE = National Study of Daily Experiences; NA = negative affect.

Table 2
Multilevel Models of Intraindividual Change in NA for the NSDE Sample

Effects type	Model A Estimate	Model A *SE*	Model B Estimate	Model B *SE*	Model C Estimate	Model C *SE*
Fixed effects						
Intercept	0.84	.038**	0.84	.042**	1.71	.124**
Day	−0.07	.005**	−0.04	.005**	−0.04	.005**
Burst	0.09	.030**	0.05	.050	0.06	.124
Baseline age	−0.01	.003**	−0.01	.002**	0.00	.003
Burst × Age	0.01	.002*	0.00	.002*	0.01	.002**
Day-level stress			0.14	.017**	0.34	.050**
Burst-level stress			0.42	.037**	0.61	.060**
Person-level stress			0.32	.039**	0.49	.061**
Burst × Day Stress			0.04	.017**	0.04	.017**
Burst × Person Stress			0.04	.033	0.04	.045
Neuroticism					0.42	.056**
Neuroticism × Burst					0.01	.051
Neuroticism × Day Stress					0.12	.028**
Neuroticism × Burst × Day Stress					0.04	.028
Random effects						
Level 3 (between-person)						
Intercept	0.48	.041**	0.37	.035**	0.32	.032**
Day-level stress			0.07	.007**	0.06	.006**
Level 2 (within-person, across bursts)						
Intercept	0.29	.025**	0.25	.022**	0.25	.022**
Level 1 (within-person, across days)						
Residual	1.04	.016**	0.90	.015**	0.90	.015**

Note. Results are on based 10,273 daily assessments ($N = 671$). NA = negative affect; NSDE = National Study of Daily Experiences.
* $p < .05$. ** $p < .01$.

the results from the NSDE data reported in Table 2. Model A in Table 4 indicates a significant but small negative association between assessment day and NA (*estimate* = −0.07, $p < .01$). There was also evidence of an increase in mean NA across bursts (*estimate* = 0.24, $p < .01$). However, the effect of baseline age was positive and not statistically significant, as opposed to negative and significant for the NSDE sample. There was also a significant interaction between baseline age and burst, indicating that that NA increased most rapidly among older individuals.

Results reported in Table 4 for Model B include the effects of day-, burst-, and person-level stress. The day-level stress effect was positive and significant (*estimate* = 0.13, $p < .01$), indicating that NA was higher on high compared with low stress days. The burst-level stress effect was not significantly different from 0 (*estimate* = 0.15, p = .07), but it was not significantly different than the day-level stress effect (*difference* = 0.02, p = .71). This result implies that the aggregated effect of daily stress within a burst does not produce an incremental effect on NA over and above the effect of stress on a given day. The person-level stress effect was positive and significant (*estimate* = 0.49, $p < .01$), indicating that individuals who reported more daily stress across the all the measurement bursts also reported higher average NA. Consistent with the results from the NSDE data, the interaction between the day-level stress effect and burst was positive (*estimate* = 0.06, $p < .01$), indicating that the average level of reactivity to daily stress increased across the 2-year follow-up period. Figure 2 shows the average day-level reactivity effects estimated separately at each burst with the linear increase trend in reactivity predicted by the significant Day-Level Stress × Burst interaction. There was also evidence of a significant Person-Level Stress × Burst interaction (*estimate* = 0.10, p = .02), indicating that individuals who reported higher average levels of daily stress exhibited the most rapid increases in NA across the follow-up period. Importantly, there was no interaction between the effect of assessment day and daily stress, indicating that reactivity was not increasing merely as a function of the number of assessments. Also, baseline age did not significantly interact with any other variable in the model.

Is There Evidence of Between-Person Stability in Emotional Reactivity?

NSDE sample. We examined the stability of reactivity to daily stress in the NSDE data by fitting a separate MLM to each burst that estimated the daily stress effect controlling for age, assessment day, and between-person differences in average daily stress. The person-specific random reactivity effects from the first and second bursts were output from each analysis and then correlated. The 10-year stability coefficient for reactivity was .37 ($p < .01$). We then computed the stability coefficient for overlapping 10-year age strata to examine whether reactivity exhibited comparable stability across most of the adult lifespan. Figure 3 plots these correlations as a function of age. The stability coefficients were highest for individuals in their 30s (.62) and 40s (.49) but exhibited a fairly consistent decline through midlife into the 60s (.21) and 70s (.18).

Table 3
Descriptive Statistics for the CHAP Sample

		Between-person correlations				
Burst	Variable	1	2	3	*M*	*SD*
1	1. Age	—			80.3	6.4
	2. Average stressor severity	−.07	—		1.4	1.4
	3. Average daily NA	.17	.32	—	1.0	1.2
	4. Global perceived stress	.14	.29	.36	17.3	6.7
2	1. Age	—			80.7	6.2
	2. Average stressor severity	−.16	—		1.5	1.4
	3. Daily NA	.05	.32	—	1.1	1.6
	4. Global perceived stress	.05	.29	.56	18.5	7.3
3	1. Age	—			81.2	6.2
	2. Average stressor severity	−.12	—		1.5	1.5
	3. Average daily NA	.11	.35	—	1.5	1.8
	4. Global perceived stress	.06	.29	.52	18.7	7.4
4	1. Age	—			81.6	6.2
	2. Average stressor severity	−.23	—		1.2	1.2
	3. Average daily NA	.20	.36	—	1.6	2.0
	4. Global perceived stress	.09	.30	.51	18.4	7.2
5	1. Age	—			82.0	6.2
	2. Average stressor severity	−.06	—		1.2	1.1
	3. Average daily NA	.22	.29	—	1.7	2.1
	4. Global perceived stress	.14	.42	.62	17.9	7.2

Note. $p < .01$ for $r > .25$; $p < .05$ for $r > .20$; *N*s = 116, 105, 97, 96, and 90 for Bursts 1–5, respectively. CHAP = Cognition, Health, and Aging Project; NA = negative affect.

We next examined whether trait neuroticism moderated reactivity as well as changes in reactivity across the 10-year follow-up. Table 1 (Model C) shows the results from this analysis. There was a significant positive relationship between neuroticism and NA (*estimate* = 0.42, $p < .01$). The Neuroticism × Daily Stress interaction was also significant (*estimate* = 0.12, $p < .01$), indicating higher levels of average reactivity among individuals with high levels of neuroticism. Neither the Neuroticism × Burst interaction nor the Neuroticism × Burst × Daily Stress interactions were significant, suggesting that neuroticism did not moderate changes in either average level of NA or reactivity.

CHAP sample. These results provide evidence that some of the variability in stress-related affect is stable and that this stability may vary across the lifespan. However, because the NSDE data consist of only two bursts, it is difficult to determine whether the within-person variability in the daily stress–affect relationship reflects uninteresting measurement error or meaningful within-person variance. We examined this issue by using the CHAP data to decompose this variability into a stable between-person component (reflecting between-person variability in the reactivity averaged across five measurement bursts) and into a within-person component (reflecting within-person variability across the five bursts). Table 4 shows the estimates for the person-level and burst-level variances in reactivity to be .03 ($p = .01$) and .08 ($p < .01$), respectively.

These results imply that approximately 27% of the variance in reactivity was at the between-person level (.03/[.03+.08]), and that 73% of the variability in reactivity transpired within-persons, across burst. In terms of Figure 1, these results demonstrate that approximately three fourths of the variance in reactivity was across columns (bursts), and about one fourth of the variability was across rows (persons). Although there is evidence of trait-like stability in reactivity to daily stress, there is also evidence of a substantial of intraindividual variability. In the next section, we attempt to model this intraindividual variability and demonstrate that it reflects systematic and meaningful variability in the daily stress–affect relationship.

Is There Evidence of Reliable Within-Person Variability in Stress-Related Affect?

We next examined how within-person and between-person variability in PSS moderated reactivity to daily stress. The PSS was measured once per measurement burst, so individuals had up to five PSS scores. The between-person PSS variable (PSS_BP) was constructed by taking the mean of each individual's PSS scores, and the within-person variable (PSS_WP) was their person-centered PSS score obtained by subtracting each person's mean PSS from their raw PSS score obtained at each burst. Table 2 (Model C) displays the results of adding these two variables and their interactions with the day-level stress variable. The PSS_BP variable was significant (*estimate* = 0.08, $p < .01$), indicating that individuals who reported higher levels of global perceived stress across the 2-year follow-up also tended to have higher levels of NA, averaged across all bursts and days. At the within-person level, PSS_WP was significant (*estimate* = 0.08, $p < .01$), indicating that individuals had higher levels of NA during bursts at which their PSS score was higher compared with bursts during which their global perceived stress was lower. The between-person PSS variable did not significantly interact with daily stress ($p = .80$), suggesting that individuals with persistently high levels of global perceived stress did not display persistently higher levels of reactivity across the 2-year follow-up. However, PSS_WP did significantly interact with the day-level stress effect (*estimate* =

Table 4
Multilevel Models of Intraindividual Change in NA for the CHAP Sample

Effects type	Model A		Model B		Model C	
	Estimate	*SE*	Estimate	*SE*	Estimate	*SE*
Fixed effects						
Intercept	1.19	.135**	1.18	.124**	1.18	.124**
Day	−0.07	.019**	−0.06	.018**	−0.06	.018**
Burst	0.24	.046**	0.25	.046**	0.25	.046**
Baseline age	0.02	.019	0.03	.016	0.03	.016
Burst × Age	0.02	.007**	0.03	.007**	0.03	.007**
Day-level stress			0.13	.045**	0.13	.045**
Burst-level stress			0.15	.080	0.09	.092
Person-level stress			0.49	.105**	0.33	.135**
Burst × Day Stress			0.06	.018**	0.05	.018**
Burst × Person Stress			0.10	.044*	0.09	.040*
PSS_WP					0.08	.011**
PSS_BP					0.08	.017**
PSS_WP × Day Stress					0.02	.001**
PSS_BP × Burst × Day Stress					0.00	.001
Random effects						
Level 3 (BP)						
Intercept	0.96	.224**	0.65	.123**	0.51	.116**
Burst	0.11	.032**	0.11	.150**	0.08	.151**
Day-level stress			0.03	.015*	0.03	.051**
Level 2 (WP, across bursts)						
Intercept	0.50	.086**	0.47	.081**	0.41	.077**
Day-level stress			0.08	.019**	0.07	.019**
Level 1 (WP, across days)						
Residual	3.03	.086**	2.65	.082**	2.64	.081**

Note. Results are on based 3,010 daily assessments (N = 116). NA = negative affect; CHAP = Cognition, Health, and Aging Project; PSS = Perceived Stress Scale; WP = within-person; BP = between-person.
* $p < .05$. ** $p < .01$.

0.02, $p < .01$), indicating that burst-to-burst fluctuations in reactivity to daily stress were coupled with concurrent fluctuations in global perceived stress.

We explored this moderation effect by examining how PSS_WP and PSS_BP related to the frequency and severity rating of daily stressors. We used a logistic regression MLM to examine changes in the probability of reporting a stressor on any given day across bursts as a function of PSS_WP and PSS_BP. There was a nonsignificant negative trend in the probability of stressor reporting across bursts (*estimate* = −0.06, p = .06, *odds ratio* = 0.94). The PSS_WP variable was positively related to burst-to-burst changes in the probability of daily stress (*estimate* = 0.10, $p < .01$, *odds ratio* = 1.10), indicating that individuals were more likely to report daily stressors during bursts in which their global perceived stress was high. There was a similar but stronger relationship at the between-person level, with PSS_BP positively associated with the probability of reporting a daily stressor (*estimate* = 1.17, $p < .01$, *odds ratio* = 3.22). Next, we modeled changes and variability in severity appraisals of daily stressors across bursts as a function of both within-person and between-person PSS variables. To distinguish between frequency and severity ratings of daily stress, we used an average severity rating for daily stressors and only included days on which a stressor occurred. There was no evidence of changes in level of severity appraisals across bursts (*estimate* = 0.02, p = .51), and there was not a significant association of PSS and severity ratings at either the between-person level (*estimate* = 0.01, p = .73) or the within-person level (*estimate* = 0.01, p = .35).

Discussion

Results from analysis of the NSDE and CHAP data converge on the following conclusions: (a) average emotional reactivity to daily stress increases in aging individuals across the adult lifespan (20s–80s), (b) there is evidence of both trait-like stability and within-person variability in emotional responses to daily stress, and (c) this within-person variability fluctuates systematically with concurrent burst-to-burst changes in global perceived stress. We now discuss the implications of these findings for understanding aging changes in daily stress processes.

Intraindividual Change in Daily Stress and NA

The demonstration of longitudinal increases in emotional reactivity to daily stress may seem to contradict the prevailing view of increasingly competent emotion regulation with advancing age (Charles & Carstensen, 2007). This view is based, in part, on two sets of findings. The first is that older adults tend rate their emotion regulation abilities more highly than younger adults (e.g., Gross et al., 1997; Lawton, Kleban, Rajagopal, & Dean, 1992; Phillips,

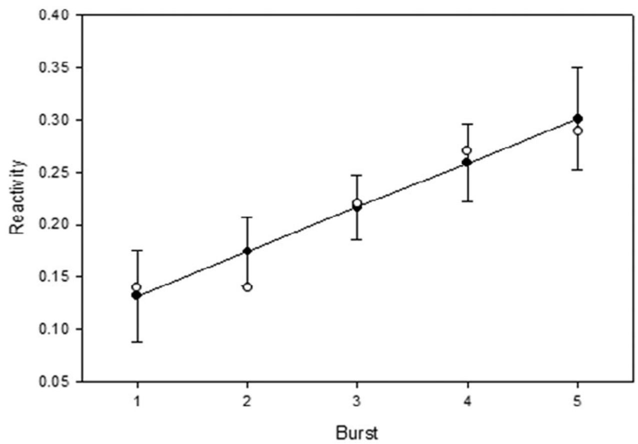

Figure 2. Average daily stress reactivity slopes across measurement burst from the Cognition, Health, and Aging Project sample. Open circles are average reactivity slopes estimated at each burst, and the filled circles represent predicted reactivity slopes (and 95% confidence limits) implied by the significant Burst × Daily Stress interaction.

Henry, Hosie, & Milne, 2006), and the second is the absence of age differences in emotional reactivity to laboratory mood induction procedures (e.g., Knight, Maines, & Robinson, 2002; Tsai, Levenson, & Carstensen, 2000). However, older adults may overestimate their emotion regulation abilities (Kunzmann, Kupperbusch, & Levenson, 2005) as well as display more reactivity than young adults when mood induction procedures rely on age-relevant content (Charles, 2005; Kunzmann & Gruhn, 2005). Age-relevant mood induction procedures rely on content that reflects actual or potential experiences (e.g., loss of a loved one to Alzheimer's disease) that a person of advanced age may encounter. Daily stressors are also emotionally relevant events because, by definition, they are events that the reporting individual appraises as presenting a challenge, threat, or potential loss. The present finding of longitudinal increases in emotional reactivity to daily stress is consistent with experimental mood induction studies that show age-related increases in emotional responses to content that older adults find personally relevant.

The demonstration of longitudinal increases in emotional reactivity to daily stress is consistent with cross-sectional evidence of age-related increases in emotional (Mroczek & Almeida, 2004) and physiological (Jennings et al., 1997; Uchino et al., 2005) reactivity to psychosocial stress. However, this results is opposite of a finding reported by Uchino et al. (2006), which showed reduced negative emotional reactivity to daily stress. One possible reason for this difference is that Uchino et al. examined reactivity to the presence of a stressor, whereas we examined reactivity in relation to subjectively rated severity. Thus, the negative events reported by older adults in their sample may have been less stressful, which could account for the negative association between age and emotional reactivity to the presence of a stressor. Future research examining age differences in reactivity as a function of other characteristics of the stressor (e.g., interpersonal vs. network vs. overload stressors) could help to clarify these discrepant results.

The present findings also appear to be at odds with cross-sectional (Isaacowitz & Smith, 2003; Mroczek & Kolarz, 1998) and longitudinal (Charles, Reynolds, & Gatz, 2001; Stacey & Gatz, 1991) studies showing age-related stability or reductions in the level of NA. However, the literature also indicates either attenuation in the decline of NA (Charles et al., 2001; Stacey & Gatz, 1991) or an actual increase during the seventh and eighth decades of life (Carstensen et al., 2000; Griffin, Mroczek, & Spiro, 2006). The present results of age-related increases in emotional reactivity to daily stress also add to a growing body of research that demands lifespan theories specify the conditions under which emotional well-being is preserved, enhanced, or impaired with advancing age.

Exposure to threatening or stressful situations may represent one condition that manifests an age-related increase in negative emotions. Older adults prefer passive emotion-focused strategies for coping with emotionally charged or stressful situations, such as deliberate withdrawal, denial, or reappraisal (Berg, Strough, Calderone, Sansone, & Weir, 1998; Blanchard-Fields, Jahnke, & Camp, 1995). Such passive strategies may be adaptive for older adults because of age-related limitations in resources required for more proactive problem-solving strategies (e.g., Blanchard-Fields, Stein, & Watson, 2004; Heckhausen & Schulz, 1995). Consequently, age-related increases in negative stress-related emotion might be amplified in situations that require problem-focused (e.g., addressing a health problem) or proactive (e.g., seeking social support) as opposed to passive (e.g., withdrawal) emotion-regulation strategies. This view is consistent with that of Labouvie-Vief (2003), who suggested that age-related declines in cognitive resources could compromise the ability of older adults to regulate negative emotions.

Could longitudinal increases in reactivity to daily stressors be attributable to a sensitization process that increases reactivity through cumulative exposure to stressors across the lifespan? Two results argue against such a process as underlying changes in reactivity. First, if a kindling process were operating, one might expect accelerated increases in reactivity with advancing age. Contrary to this expectation, age did not interact with the rate of

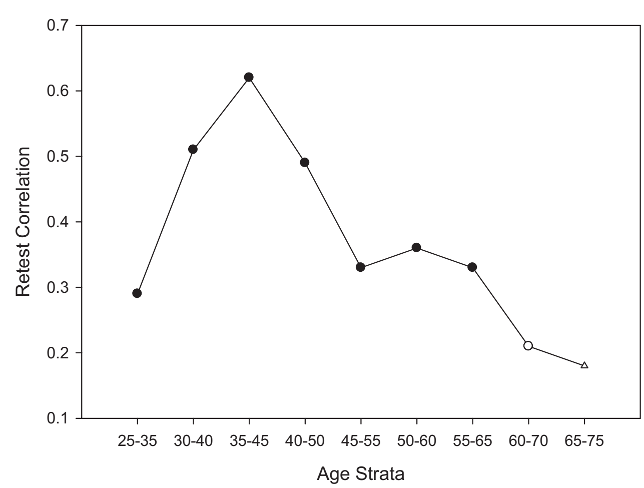

Figure 3. Ten-year retest correlations for reactivity to daily stress in the National Study of Daily Experiences sample as a function of baseline age. Probability values for correlations are depicted by the following: filled circles ≤ .01, open circle = .08, and triangle = .18.

change in reactivity in either the NSDE or CHAP data. Second, individuals with high levels of neuroticism report more frequent and severe stressors, suggesting that more pronounced sensitization and greater increases in reactivity should accompany higher levels of trait neuroticism—but this was not the case in the NSDE data. Although a more definitive test of the kindling hypothesis would require direct examination of age changes in neural and physiological sensitivity to stress, the present results are not entirely consistent with a stress sensitization account.

Between-Person Stability and Intraindividual Variability in Stress Reactivity

The present results provide evidence that both stable characteristics of individuals as well as transient characteristics of their broader psychosocial context are relevant for emotional responses to daily stressors. Data from the NSDE indicated impressive 10-year stability of individual differences from for adults in their 30s and 40s (retest correlations ranging from .49 to .62). However, stability declined through midlife (ages 50–65 years: retest correlations in the .30s) into older age (ages 60–75 years: retest correlations of about .20). This decline in stability could reflect an age-related reduction in between-person variability in reactivity attributable due to selective mortality. If reactivity is a trait-like characteristic and it entails increased risk for disease and mortality, then persons displaying high reactivity would be underrepresented in old age. Age differences in longitudinal stability might also reflect changes in stressor content resulting from developmental transitions through adulthood (e.g., more work overload stressors in midlife giving way to health related stressors in older age). Environmental factors and psychosocial contexts (e.g., available social support) may also play an increasingly important role in old age for determining reactivity to daily stressors, lessening the influence of trait determinants of reactivity.

This later possibility is especially relevant for interpreting the results from the CHAP sample, which showed that only about 27% of the reliable variance in reactivity across 6-month retest intervals was attributable to stable individual differences in adults in their 70s and 80s. This implies that the amount of reactivity exhibited by a given person during a given week reflects to greater degree transient characteristics specific to that particular week than enduring characteristics of the person. Analysis of global perceived stress revealed the importance of within-person variability in psychosocial context for predicting reactivity. Burst-to-burst intraindividual variability in PSS predicted concurrent burst-to-burst variability in reactivity—the coupling of daily stress and NA was amplified at times during which current demands and problems were viewed as overwhelming or uncontrollable.

Van Eck et al. (1998) speculated that amplified mood responses to daily stress associated with high global perceived stress might reflect a "process of sensitization to stress—for example, due to prior exposure to life events or cumulative exposure to minor daily events in the recent past" (p. 1582). Consistent with this view, the probability of stressful events was positively associated with within-person variability in PSS across bursts, a finding that parallels cross-sectional results reported by van Eck et al. showing PSS correlated with frequency but not with severity of daily everyday stressors. Sensitization to daily stressors resulting from cumulative exposure to stress would predict that individuals with high average PSS scores (i.e., greater cumulative exposure across entire follow-up period) exhibit greater emotional reactivity, which was not the case. If sensitization did occur, it would have to reflect the effects of current rather than cumulative exposure to stress. Transient loss (and gains) in available resources provide an alternative account of the within-person association between PSS and reactivity. Individuals may have fewer available resources to deal with daily stressors during times when, at a more global level, life's demands seem overwhelming and uncontrollable, especially in older adults. These results suggest the utility of viewing emotional responses to stress as a function not only of the person but also of the psychosocial context in which the stressful event occurs.

The present findings have broader implications for longitudinal studies of intraindividual change and variability in the context of aging research. Studies that rely on sampling experiences during a narrow temporal epoch (e.g., a given week) cannot distinguish stable between-person effects that would persist across long time periods (e.g., a personality trait) from the effects of slow-state variables that are relatively constant within a given time period but that vary at monthly rather daily cadence (e.g., available social support). Use of the measurement-burst design recognizes that an individual's current state reflects the following: (a) momentary influences of mood and daily experiences, (b) contextual influences of dynamic psychosocial processes that change across weeks and months, (c) very slow acting aging processes that manifest across years and decades, and (d) stable individual differences that persist across long segments of the adult lifespan. An important challenge in developmental research is to identify and establish causal links among processes that transpire at the micro (e.g., momentary, daily) and macro (e.g., monthly, yearly) time scales.

Limitations and Conclusions

There are several important limitations that apply to the present analyses. First, our use of the term *reactivity* implies that within-person changes in mood states resulted from proximal changes in stress, and not visa versa. Although previous studies have established evidence consistent with reactivity by showing prior stress predicting subsequent mood changes (e.g., van Eck et al., 1998), data from the NSDE and CHAP studies do not provide the temporally fine-grained assessments necessary to test this assumption. This limitation leaves open the possibility of age differences in thresholds for reporting daily stressors that might be influenced by current mood states. Additional research is needed that offers more temporally fine-grained, within-day assessments of events and mood states to address this limitation.

Second, these data come from two different studies, with different sampling and assessment procedures. Although this complicates direct comparison of effect sizes (e.g., stability coefficients, rates of change), it makes the similarity of results all the more impressive. Third, there was a lack of convergence of cross-sectional and longitudinal age trends for a number of results. For example, both studies showed intraindividual increases in reactivity to daily stress, although neither study showed age differences in reactivity at cross-section. Similarly, both studies showed longitudinal (within-person) increases in average NA that were not supported by cross-sectional (between-person) comparison of age differences. These discrepant results could reflect cohort differences contaminating cross-sectional estimates of age effects, especially because the NSDE study consists of an extremely age-heterogeneous sample. Also, the longitudinal estimates of age changes may reflect unique period effects (e.g., after the attacks of 9/11/2001). Fourth, no measures of personality traits were available for the CHAP data, so it was not possible to compare the relative importance of stable person characteristics (e.g., neuroticism) and current psychosocial context (e.g., global perceived stress). Finally, within-person variability in reactivity could not be examined in the NSDE data, so it is not clear whether results found in older adults with the CHAP data would generalize to early portions of the adult lifespan.

Despite these limitations, the joint analyses of these two data sets paint a coherent picture of increased coupling of daily stress and NA in aging individuals across most of the adult lifespan. The measurement-burst designs provide a unique demonstration of moderate and age-dependent long-term stability in affective responses to everyday stress, but they also demonstrate the presence and importance of within-person variability in reactivity across-bursts. If persistently high levels of stress-related NA increase disease risk, it might not matter whether that heightened response is due to a characteristic of the person or of their environment. These findings suggest that future research on daily stress processes examine not only stable characteristics of the person (e.g., personality traits) that might influence responses to every challenges and problems but also variables that reflect dynamic characteristics of the psychosocial context in which these challenges occur.

References

Almeida, D. M. (2005). Resilience and vulnerability to daily stressors assessed via dairy methods. *Current Directions in Psychological Science, 14,* 64–68.

Almeida, D. M., Wethington, E., & Kessler, R. C. (2002). The Daily Inventory of Stressful Events: An interview-based approach for measuring daily stressors. *Assessment, 9,* 41–55.

Berg, C. A., Strough, J., Calderone, K. S., Sansone, C., & Weir, C. (1998). The role of problem definitions in understanding age and context effects on strategies for solving everyday problems. *Psychology and Aging, 13,* 29–44.

Blanchard-Fields, F., Jahnke, H. C., & Camp, C. (1995). Age differences in problem solving style: The role of emotional salience. *Psychology and Aging, 10,* 173–180.

Blanchard-Fields, F., Stein, R., & Watson, T. L. (2004). Age differences in emotion-regulation strategies in handling everyday problems. *Journals of Gerontology: Psychological Sciences and Social Sciences, 59*(B), P261–P269.

Bolger, N., & Schilling, E. A. (1991). Personality and problems of everyday life: The role of neuroticism in exposure and reactivity to daily stressors. *Journal of Personality, 59,* 356–386.

Bolger, N., & Zuckerman, A. (1995). A framework for studying personality in the stress process. *Journal of Personality and Social Psychology, 69,* 890–902.

Bradburn, N. M. (1969). *The structure of psychological well-being.* Chicago, IL: Aldine.

Cacioppo, J. T., Berntson, G. G., Malarkey, W. B., Kiecolt-Glaser, J. K., Sheridan, J. F., Poehlmann, K. M., et al. (1998). Autonomic, neuroendocrine, and immune responses to psychological stress: The reactivity hypothesis. *Annals of the New York Academy of Sciences, 840,* 664–673.

Carstensen, L. L. (1995). Evidence for a life-span theory of socioemotional selectivity. *Current Directions in Psychological Science, 4,* 151–156.

Carstensen, L. L., Pasupathi, P., Mayr, U., & Nesselroade, J. R. (2000). Emotional experience in everyday life across the adult life span. *Journal of Personality and Social Psychology, 79,* 644–655.

Charles, S. T. (2005). Viewing injustice: Age differences in emotional experience. *Psychology and Aging, 20,* 159–164.

Charles, S. T., & Carstensen, L. L. (2007). Emotion regulation and aging. In J. J. Gross (Ed.), *Handbook of emotion regulation* (pp. 307–320). New York, NY: Guilford Press.

Charles, S. T., & Piazza, J. R. (2007). Memories of social interactions: Age differences in emotional intensity. *Psychology and Aging, 22,* 300–309.

Charles, S., Reynolds, C. A., & Gatz, M. (2001). Age-related differences and change in positive and negative affect over 23 years. *Journal of Personality and Social Psychology, 80,* 136–151.

Cohen, S., Hamrick, N., Rodriguez, M. S., Feldman, P. J., Rabin, B. S., & Manuck, S. B. (2000). The stability of and intercorrelations among cardiovascular, immune, endocrine, and psychological reactivity. *Annals of Behavioral Medicine, 22,* 1–10.

Cohen, S., Kamarck, T., & Mermelstein, R. (1983). A global measure of perceived stress. *Journal of Health and Social Behavior, 24,* 385–396.

Griffin, P. W., Mroczek, D. K., & Spiro, A., III. (2006). Variability in affective change among aging men: Longitudinal findings from the VA Normative Aging Study. *Journal of Research in Personality, 40,* 942–965.

Gross, J. J., Carstensen, L. C., Pasupathi, M., Tsai, J., Gottestam, K., & Hsu, A. Y. C. (1997). Emotion and aging: Experience, expression, and control. *Psychology and Aging, 12,* 590–599.

Heckhausen, J., & Schulz, R. (1995). A life-span theory of control. *Psychological Review, 102,* 284–304.

Isaacowitz, D. M., & Smith, J. (2003). Positive and negative affect in very old age. *Journals of Gerontology: Psychological Sciences, 58*B, P143–P152.

Jennings, J. R., Kamarck, T., Manuck, S., Everson, S. A., Kaplan, G., & Salonen, J. T. (1997). Aging or disease? Cardiovascular reactivity in Finish men over the middle years. *Psychology and Aging, 12,* 225–238.

Kendler, K. S., Thornton, L. M., & Gardner, C. O. (2001). Genetic risk, number of previous depressive episodes, and stressful life events in predicting onset of major depression. *American Journal of Psychiatry, 158,* 582–586.

Kessler, R. C., MacGonagle, K. A., Zhao, S., Nelson, C. B., Hughes, M., Eshleman, S., et al. (1994). Lifetime and 12-month prevalence of *DSM–III–R* psychiatric disorders in the United States. *Archives of General Psychiatry, 51,* 8–19.

Knight, B. G., Maines, M. L., & Robinson, G. S. (2002). The effects of sad mood on memory in older adults: A test of the mood congruence effect. *Psychology and Aging, 17,* 653–661.

Kunzmann, U., & Gruhn, D. (2005). Age differences in emotional reactivity: The sample case of sadness. *Psychology and Aging, 20,* 47–59.

Kunzmann, U., Kupperbusch, C. S., & Levenson, R. W. (2005). Behavioral inhibition and amplification during emotional arousal: A comparison of two age groups. *Psychology and Aging, 20,* 144–158.

Labouvie-Vief, G. (2003). Dynamic integration: Affect, cognition, and the self in adulthood. *Current Directions in Psychological Science, 12,* 201–206.

Lachman, M. E., & Weaver, S. L. (1998). The sense of control as a moderator of social class differences in health and well-being. *Journal of Personality and Social Psychology, 74,* 763–773.

Lawton, M. P., Kleban, M., Dean, J., Rajagopal, D., & Parmelee, P. (1992). The factorial generality of brief positive and negative affect measures. *Journal of Gerontology: Psychological Sciences, 47,* 228–237.

Lawton, M. P., Kleban, M. H., Rajagopal, D., & Dean, J. (1992). Dimensions of affective experience in three age groups. *Psychology and Aging, 7,* 171–184.

Lazarus, R. S. (1999). *Stress and emotion: A new synthesis.* New York, NY: Springer.

Lazarus, R. S., & Folkman, S. (1984). *Stress, appraisal, and coping.* New York, NY: Springer.

Mroczek, D. K., & Almeida, D. M. (2004). The effect of daily stress, personality, and age on daily negative affect. *Journal of Personality, 72,* 355–378.

Mroczek, D. K., & Kolarz, C. M. (1998). The effect of age on positive and negative affect: A developmental perspective on happiness. *Journal of Personality and Social Psychology, 75,* 1333–1349.

Mroczek, D. K., Spiro, A., Griffin, P. W., & Neupert, S. D. (2006). Personality and aging. In J. E. Birren & K. W. Schaie (Eds.), *Handbook of the psychology of aging* (6th ed., pp. 363–377). Amsterdam, the Netherlands: Elsevier.

Nesselroade, J. R. (1991). The warp and woof of the developmental fabric. In R. Downs, L. Liben, & D. S. Palermo (Eds.), *Visions of aesthetics, the environment, and development: The legacy of Joachim F. Wohwill* (pp. 213–240). Hillsdale, NJ: Erlbaum.

Phillips, L. H., Henry, J. D., Hosie, J. A., & Milne, A. B. (2006). Age, anger regulation, and well-being. *Aging and Mental Health, 10,* 250–256.

Radloff, L. S. (1977). The CES-D Scale: A self-report depression scale for research in the general population. *Applied Psychological Measurement, 1,* 385–401.

Raudenbush, S. W., & Bryk, A. S. (2002). *Hierarchical linear models: Applications and data analysis methods* (2nd ed.). London, England: Sage.

Sliwinski, M. (2008). Measurement-burst designs for social health research. *Social and Personality Psychology Compass, 2,* 245–261.

Snidjers, T. A. B., & Bosker, R. J. (1999). *Multilevel analysis: An introduction to basic and advanced multilevel modeling.* London, England: Sage.

Stacey, C. A., & Gatz, M. A. (1991). Cross-sectional age differences and longitudinal change on the Bradburn Affect Balance Scale. *Journal of Gerontology: Psychological Sciences, 45,* P76–P78.

Stawski, R. S., Sliwinski, M. J., Almeida, D. M., & Smyth, J. M. (2008). Reported exposure and emotional reactivity to daily stressors: The roles of adult-age and global perceived stress. *Psychology and Aging, 23,* 52–61.

Stone, A. A., Marco, C. A., Cruise, C. E., Cox, D. S., & Neale, J. M. (1996). Are stress-induced immunological changes mediated by mood? A closer look at how both desirable and undesirable daily events influence sIgA antibody. *International Journal of Behavioral Medicine, 3,* 1–13.

Taylor, J. A. (1953). A personality scale of manifest anxiety. *Journal of Abnormal and Social Psychology, 48,* 285–290.

Tsai, J. L., Levenson, R. W., & Carstensen, L. L. (2000). Autonomic, expressive, and subjective responses to emotional films in older and younger Chinese American and European American adults. *Psychology and Aging, 15,* 684–693.

Turner, H., & Turner, R. J. (2005). Understanding variations in exposure to social stress. *Health, 9,* 209–240.

Turner, R. J., Wheaton, B., & Lloyd, D. A. (1995). The epidemiology of social stress. *American Sociological Review, 60,* 104–125.

Uchino, B. N., Berg, C. A., Smith, T. W., Pearce, G., & Skinner, M. (2006). Age-related differences in ambulatory blood pressure reactivity during stress: Evidence for greater blood pressure reactivity with age. *Psychology and Aging, 21,* 231–239.

Uchino, B. N., Holt-Lunstad, J., Bloor, L. E., & Campo, R. A. (2005). Aging and cardiovascular reactivity to stress: Longitudinal evidence for changes in stress reactivity. *Psychology and Aging, 20,* 134–143.

van der Kolk, B. A. (1997). Traumatic memories. In P. S. Appelbaum, L. A. Uyehara, & M. R. Elin (Eds.), *Trauma and memory: Clinical and legal controversies* (pp. 243–260). New York, NY: Oxford University Press.

van Eck, M., Berkhof, H., Nicolson, N., & Sulon, J. (1996). The effects of perceived stress, traits, mood states, and stressful daily events on salivary cortisol. *Psychosomatic Medicine, 58,* 447–459.

van Eck, M., Nicolson, N. A., & Berkhof, J. (1998). Effects of stressful daily events on mood states: Relationship to global perceived stress. *Journal of Personality and Social Psychology, 75,* 1572–1585.

Whitbourne, S. K. (1985). The psychological construction of the life span. In J. E. Birren & K. W. Schaie (Eds.), *Handbook of the psychology of aging: The handbooks of aging* (2nd ed., pp. 594–618). New York, NY: Van Nostrand Reinhold.

Whitbourne, S. K. (1986). Openness to experience, identity flexibility, and life change in adults. *Journal of Personality and Social Psychology, 50,* 163–168.

Woolf, C. J., & Costigan, M. (1999). Transcriptional and posttranslational plasticity and the generation of inflammatory pain. *Proceedings of the National Academy of Sciences, USA, 96,* 7723–7730.

Zautra, A. J. (2003). *Emotions, stress, and health.* New York, NY: Oxford University Press.

Zautra, A. J., Affleck, G. G., Tennen, H., Reich, J. W., & Davis, M. C. (2005). Dynamic approaches to emotions and stress in everyday life: Bolger and Zuckerman reloaded with positive as well as negative affect. *Journal of Personality, 73,* 1511–1538.

Received October 1, 2008
Revision received September 21, 2009
Accepted September 25, 2009 ■