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Original Research Report

Relationships Among Nightly Sleep Quality, Daily Stress, and Daily Affect

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Abstract

Objectives. We explored the prospective, microlevel relationship between nightly sleep quality (SQ) and the subsequent day's stress on positive (PA) and negative affect (NA) as well as the moderating relationships between nightly SQ, subsequent stress, and subsequent PA on NA. We investigated whether age moderated these relationships.

Method. We collected 56 days of sleep, stress, and affect data using daily diary questionnaires ($N = 552$). We used multilevel modeling to assess relationships at the between- and within-person levels.

Results. Daily increases in SQ and decreases in stress interacted to predict higher daily PA and lower daily NA. Better SQ in older adults enhanced the benefits of PA on the stress–NA relationship more during times of low stress, whereas better sleep in younger adults enhanced the benefits of PA more during times of high stress. Between-person effects were stronger predictors of well-being outcomes than within-person variability.

Discussion. The combination of good SQ and higher PA buffered the impact of stress on NA. The moderating impact of age suggests that sleep and stress play different roles across adulthood. Targeting intervention and prevention strategies to improve SQ and enhance PA could disrupt the detrimental relationship between daily stress and NA.

Keywords: Affect—Daily diary—Intraindividual variability—Sleep—Stress

Contextual factors can either exacerbate or diminish the strength of the relationship between perceived stress and negative affect, particularly at the daily level (Ong, Bergeman, Bisconti, & Wallace, 2006). Sleep research shows linkages between sleep quality (SQ) and perceived stress (Åkerstedt et al., 2012), as well as SQ and positive (PA) and negative affect (NA; Bower, Bylsma, Morris, & Rottenberg, 2010; Gujar, McDonald, Nishida, & Walker, 2010; Walker & Tharani, 2009). Whereas poor sleep accentuates NA (e.g., anger or nervousness; Watson, Clark, & Tellegen, 1988) and inhibits positive emotions (Gujar et al., 2010; Walker & Tharani, 2009), good sleep promotes PA (e.g., interest or attentiveness; Watson et al., 1988) and protects against negative emotions (Bower et al., 2010; Cunningham et al., 2014; Gujar et al., 2010; Walker & Tharani, 2009). Positive emotions themselves also protect the individual from the harmful consequences of stress (Fredrickson 2004; Ong & Bergeman, 2010; Ong, Bergeman, & Bisconti, 2004; Ong, Bonanno, & Bergeman, 2014). Aging research illustrates that stress, SQ, and affect change across development (Carstensen & Mikels, 2005; Charles & Piazza, 2009; Klerman & Dijk, 2008; Lachman, 2004).

The majority of sleep research cross-sectionally examines sleep between individuals. Interindividual research cannot be used to understand within-person variability, emphasizing the need to explore daily fluctuations of sleep

within individuals over time (Brose, Schmiedek, Lövdén, Molenaar, & Lindenberger, 2010; Molenaar, 2004; Molenaar & Campbell, 2009). Therefore, the current study uses the analytic approach of multilevel modeling to explore the prospective, dynamic, microlevel impact of nightly SQ on the subsequent day's stress and affect. Using 56 days of daily data in a midlife and later-life cohort in which each participant serves as their own control, we assess the impact of nightly SQ and daily stress on affect, the relationships between nightly SQ, daily stress, and daily PA on NA, and whether the relationships differ by age (see Supplementary Figure 1 for a model of the study's tests).

Research shows that the relationship between daily stress and daily NA (i.e., stress reactivity) affects physical and emotional well-being as much as 10 years later (Charles, Piazza, Mogle, Sliwinski, & Almeida, 2013; Piazza, Charles, Sliwinski, Mogle, Almeida, 2013). Specifically, individuals who experienced a greater difference in their NA on stressful compared with nonstressful days reported more affective distress (Charles et al., 2013) and poorer chronic health (Piazza et al., 2013) 10 years after daily assessments. Because research illustrates that the linkage between stress and NA affects well-being, the current study explores whether other contextual factors, specifically SQ and PA, affect the stress–NA relationship.

Good SQ benefits the brain, returning it to homeostasis, clearing the brain of toxins, and preparing it for the next day (Dement & Vaughan, 1999; McEwen, 2006; Xie et al., 2013). Poor sleep worsens the negative outcomes associated with stress by making an individual cognitively, emotionally, and physiologically more vulnerable to stressful events (Åkerstedt et al., 2012; Dement & Vaughan, 1999; Payne, 2011; Walker, 2009). Similarly, sleep loss detrimentally affects the processing of emotional information and results in greater attention to negative emotions (Gujar et al., 2010; Walker & Tharani, 2009), whereas good sleep is associated with better emotion regulation and greater positive emotions (Bower et al., 2010; Cunningham et al., 2014; Gujar et al., 2010; Walker & Tharani, 2009).

Walker and Tharani (2009) explored differences in memory of emotionally laden words between an experimentally sleep-deprived group and a group who had been allowed to sleep. Results indicated that sleep-deprived participants remembered significantly fewer positive emotion and neutral words but showed no differences in memory of negatively emotionally primed words compared with those who were allowed to sleep. Similarly, when participants rated emotional facial expressions on an emotional gradient, participants who slept during a nap showed greater emotional sensitivity to happy expressions compared with participants who did not sleep. Participants who did not sleep also reported higher sleepiness ratings and showed greater emotional sensitivity to fear and anger expressions (Gujar et al., 2010). Upon examining the relationship between SQ and PA, researchers found that SQ significantly predicted PA after controlling for depression diagnoses (Bower et al., 2010). This research illustrates that sleep deprivation inhibits positive emotions and accentuates negative emotions, whereas good sleep promotes positive emotions. When examining these relationships prospectively at the daily level, we first explore whether good nightly SQ buffers (moderates) the effects of the subsequent day's daily stress on PA and NA.

Like good SQ, PA also protects individuals from negative emotional outcomes. Fredrickson (2004) provided an evolutionary explanation for the purpose and function of positive emotions, suggesting that they promote adaptive behaviors and have an "undoing effect" on the individual—essentially reversing the effects of negative emotions over time. Exhibiting positive emotions within stressful circumstances can ameliorate the damaging effects of stress by countering the consequences of negative emotions (Folkman & Moskowitz, 2000; Fredrickson, 2004; Ong et al., 2004; Ong et al, 2006; Ong & Bergeman, 2010; Ong et al., 2014). For example, examining the effect of positive emotions on stress and negative emotions in a sample of recently bereaved widows showed that higher levels of within-person daily positive emotions buffer the effect of daily stress on daily negative emotions (Ong et al., 2004). This finding held in a normative sample (Ong et al., 2006). These findings illustrate the buffering effect of PA on the relationship between daily stress and daily NA. Because good SQ is associated with positive emotions, and because positive emotions "undo" negative emotions, and protect against the negative ramifications associated with stress, the second aim of the current study is to explore the impact of good nightly SQ on the relationship between the subsequent day's stress, PA, and NA. Although researchers' language regarding these relationships refers to a "buffering" (moderating) effect of PA on the relationship between stress and NA, the "undoing" hypothesis may be better represented as a mediator of the stress–NA relationship. The thinking here is that if PA "undoes" the effect of stress on NA, then that relationship should decrease or disappear when PA is added into the model (Baron & Kenny, 1986). Thus, we will also test whether daily PA mediates the relationship between nightly SQ and subsequent stress on NA.

As individuals enter different developmental periods, they experience changes in stress (Charles & Piazza, 2009). Whereas adults in midlife struggle to balance stress associated with work, family, health, and hobbies (Lachman, 2004), older adults typically have fewer social roles that compete for their energies (Pearlin & Skaff, 1996). During midlife, adults also begin to experience greater health problems (Lachman, 2004), which may both result from stress and serve as new stressors (McEwen & Seeman, 1999). In addition, older adults process emotional information differently, placing greater emphasis on emotional regulation and illustrating greater attention, memory, and neurological reactivity for positive material (Carstensen & Mikels, 2005). Furthermore, research shows that average levels of negative life events are less related to depressive

symptoms among adults in later life versus those in midlife (Whitehead & Bergeman, 2014). Similarly, the detrimental relationship between less variability in negative life events and high average levels of negative life events on depressive symptoms affects midlife adults more so than those in later life (Whitehead & Bergeman, 2014). These studies suggest that younger adults may be more susceptible to the negative effects of stress and less influenced by the benefits of positive emotions compared with older adults.

Sleep structure also changes across development (Dillon et al., 2015; Klerman & Dijk, 2008; Van Reeth et al., 2000). Sleep problems are frequently reported issues that arise during midlife (Lachman, 2004). This could be partly due to the increase in role demands, which increases stress, contributes to a physiological toll, and then affects the sleep–wake cycle (McEwen & Seeman, 1999). It is possible that because adults in midlife often obtain less than optimal sleep, they become less resilient to the negative emotional and physiological effects of stress, creating a downward cyclical pattern in which poor SQ results in greater reactivity to stress, and stress reactivity results in even less effective sleep patterns.

Suboptimal aging in later life can result in altered sleep architecture and quality for a whole host of different reasons compared with those of midlife adults. Specifically, adults in later life tend to experience less stress associated with social roles (Pearlin & Skaff, 1996) but may face a variety of other physiological, cognitive, and interpersonal challenges (Gamaldo et al., 2014; Roepke & Ancoli-Israel, 2010; Vitiello, 2009). Research generally shows that adults in later life have less overall sleep time and efficiency as well as greater nighttime interruptions (Unruh et al., 2008; Vitiello, 2009). Although aging is associated with objectively less overall sleep time and efficiency and greater nighttime interruptions (Van Reeth et al., 2000), subjective SQ among older adults accounts for more of the variance in negative outcomes than does objective SQ (McCrae et al., 2008). Furthermore, although within-person variability in aspects of SQ is negatively associated with age, this within-person variability is larger than between-person differences in SQ (Dillon et al., 2015). These findings emphasize the importance of studying intraindividual variability in subjective SQ and interindividual differences in that variability. We can then observe the impact of daily fluctuations in SQ for any one individual as well as whether those fluctuations differ depending on age. The third aim of the current study is to assess the moderating role of age on the constructs of interest.

The model of the current study is depicted in Supplementary Figure 1. The purpose of the study is threefold. First, to explore the within- and between-person main effects of stress and SQ on affect with a primary focus on the intraindividual relationship between nightly subjective SQ and subsequent stress on daily PA and NA assessed across a 56-day period. Second, the within-person and between-person main effects of SQ, stress, and PA on NA, as well as the intraindividual relations between nightly SQ, with the subsequent day's stress and PA on NA will be explored. Finally, we will assess whether age moderates the effects. Multilevel modeling (MLM) allows us to parse interindividual differences from within-person variation and compare interindividual differences with the intraindividual effects (Hoffman & Stawski, 2009; Wang & Maxwell, 2015). Results of this type will contribute to a better understanding of the important contextual role of SQ in the complex relations among stress and emotional well-being.

Method

Sample

The participants include two cohorts from the Notre Dame Study of Health & Well-Being (NDHWB), a longitudinal study that conducts both yearly assessments of participants' overall emotional and physical health and a 56-day burst collection of data (see Bergeman & Deboeck, 2014). The midlife cohort consists of 307 individuals aged 33–64 years (M = 54.28, SD = 6.19). These questionnaires were distributed to and collected from the participants from July 2009 through October 2010. The cohort was predominantly women (61%) and White (89%). The later-life cohort consists of 245 individuals aged 62–91 years (M = 72.05, SD = 4.55). This cohort was 63% women and 86% White. The questionnaires for this cohort were distributed to and collected from participants from April 2010 through November 2011. For the purposes of the current study, the cohorts were combined to form one sample (62% women; M = 62.18; SD = 10.42).

Procedure

After completing a yearly questionnaire that assesses various aspects of well-being, participants were asked to participate in a 56-day daily diary study, 94% of the midlife cohort and 93% of the later-life cohort participated. Participants completed the daily questionnaire by answering questions about SQ from the night before upon waking and then answering questions about that day's stress, PA, and NA during the evening. Participants received a $10 gift card in exchange for mailing back each week of diaries, totaling $80 for the completion of 8 weeks of data. We expected a total of 30,912 days of data based on the number of participants in the study and received a total of 26,846 daily diaries, illustrating that the participants completed 87% of the daily questionnaires.

Measures

Daily Stress

Daily stress levels were assessed using the 10-item Perceived Stress Scale (Cohen & Williamson, 1988). Response options used a 4-point Likert scale. The measure includes items such as "Today I was upset because of something

that happened unexpectedly," or "Today I felt nervous and 'stressed.'" Cronbach's alpha on Day 1 was .90.

Positive and Negative Affect

Daily responses on the Positive and Negative Affect Schedule (Watson, Clark, & Tellegen, 1988) were used to assess positive and negative emotions. The current measure contains the original 20 items used to assess PA (i.e., "enthusiastic") and NA (i.e., "afraid") and seven additional items added to assess lower levels of emotional arousal (e.g., sad, content). Participants were asked to report the extent to which they felt each emotion on that day using a 5-point scale. Cronbach's alpha on Day 1 was .94 for NA and .94 for PA.

Nightly SQ

The Karolinska Sleep Diary (Akerstedt, Hume, Minors, & Waterhouse, 1994) was used to assess SQ. The current study summed five items from the Karolinska Sleep Diary (i.e., subjective quality, restfulness, ease of falling asleep, ease of waking, and feeling rested), with an additional item assessing sleep sufficiency, to determine SQ. The items used a 5-point semantic differential scale. The SQ scores were reverse coded so that higher scores represented better SQ. Cronbach's alpha on Day 1 was .87.

Analytic Approach

All aims were explored using MLM. As suggested by Wang and Maxwell (2015), we centered all predictor variables at Level 1 using person-mean centering, which allowed us to parse the between-person effects from the within-person effects (Curran & Bauer, 2011; Hoffman & Stawski, 2009). We centered the person means at Level 2 using grand mean centering so the intercept would reflect the sample average. We included time as a Level 1 covariate to control for its effects and investigate the within-person effects sans the time effects. For each main effects model, we contrasted the within- and between-person effects to test whether there were significant differences (Wang & Maxwell, 2015). Specifically, we tested whether the difference between the average within-person effect and the between-person effect was significant using the "ESTIMATE" command in SAS. Because participants reported last night's SQ on the same day as they reported their subsequent affect, the previous day's affect was not included in the models.

The first set of analyses examined the effects of stress and SQ on PA and NA and tested the hypothesis that SQ buffers the effects of stress on PA and NA. The final model controls for time and examines the SQ (γ_{01}), stress (γ_{02}), and age (γ_{03}) effects between individuals and the SQ (γ_{20}), stress (γ_{30}), and interaction (γ_{21}–γ_{41}) effects within individuals. The model allows the intercept, time, and intraindividual sleep and stress to be random as indicated in the following equation:

$$\begin{aligned}\text{Daily affect}_{ij} = {} & \gamma_{00} + \gamma_{01}(\text{SQ}_i) + \gamma_{02}(\text{Stress}_i) \\ & + \gamma_{03}(\text{Age}_i) + u_{0i} + \gamma_{10}(\text{Time} - 1_{ij}) \\ & + \gamma_{20}(\text{SQ}_{ij}) + \gamma_{30}(\text{Stress}_{ij}) \\ & + \gamma_{21}(\text{Age}_i * \text{SQ}_{ij}) + \gamma_{31}(\text{Age}_i * \text{Stress}_{ij}) \\ & + \gamma_{40}(\text{SQ}_{ij} * \text{Stress}_{ij}) \\ & + \gamma_{41}(\text{Age}_i * \text{SQ}_{ij} * \text{Stress}_{ij}) + u_{1i}(\text{Time} - 1_{ij}) \\ & + u_{3i}(\text{SQ}_{ij}) + u_{4i}(\text{Stress}_{ij}) + e_{ij}.\end{aligned} \quad (1)$$

The second set of analyses examined the effects of SQ, stress, and PA on NA by age and tested the hypotheses that PA buffers the effect of stress on NA, SQ enhances the negative association between PA and NA, and PA mediates the relationship between stress and SQ on NA. The final model includes the interindividual main effects of SQ (γ_{01}), stress (γ_{02}), PA (γ_{03}), and age (γ_{04}), the intraindividual main effects of SQ (γ_{20}), stress (γ_{30}), and PA (γ_{40}), and the two-way (γ_{21}–γ_{70}), three-way (γ_{51}–γ_{80}), and four-way interactions (γ_{81}). The model allows the intercept, time, and intraindividual SQ, stress, and PA to be random as indicated in the following equation:

$$\begin{aligned}\text{NA}_{ij} = {} & \gamma_{00} + \gamma_{01}(\text{SQ}_i) + \gamma_{02}(\text{Stress}_i) + \gamma_{03}(\text{PA}_i) \\ & + \gamma_{04}(\text{Age}_i) + u_{0i} + \gamma_{10}(\text{Time} - 1) + \gamma_{20}(\text{SQ}_{ij}) \\ & + \gamma_{30}(\text{Stress}_{ij}) + \gamma_{40}(\text{PA}_{ij}) + \gamma_{21}(\text{Age}_i * \text{SQ}_{ij}) \\ & + \gamma_{31}(\text{Age}_i * \text{Stress}_{ij}) + \gamma_{41}(\text{Age}_i * \text{PA}_{ij}) \\ & + \gamma_{50}(\text{SQ}_{ij} * \text{Stress}_{ij}) + \gamma_{60}(\text{SQ}_{ij} * \text{PA}_{ij}) \\ & + \gamma_{70}(\text{Stress}_{ij} * \text{PA}_{ij}) + \gamma_{51}(\text{Age}_i * \text{SQ}_{ij} * \text{Stress}_{ij}) \\ & + \gamma_{61}(\text{Age}_i * \text{SQ}_{ij} * \text{PA}_{ij}) \\ & + \gamma_{71}(\text{Age}_i * \text{Stress}_{ij} * \text{PA}_{ij}) \\ & + \gamma_{80}(\text{SQ}_{ij} * \text{Stress}_{ij} * \text{PA}_{ij}) \\ & + \gamma_{81}(\text{Age}_i * \text{SQ}_{ij} * \text{Stress}_{ij} * \text{PA}_{ij}) \\ & + u_{1i}(\text{Time} - 1_{ij}) + u_{2i}(\text{SQ}_{ij}) + u_{3i}(\text{Stress}_{ij}) \\ & + u_{4i}(\text{PA}_{ij}) + e_{ij}.\end{aligned} \quad (2)$$

Results

Descriptive Statistics

Descriptive statistics comparing the sample on demographic variables are presented in Table 1. Descriptive statistics for each variable of interest are presented in Table 2. Women reported greater stress (M = 18.48; SD = 4.31) than men (M = 17.72; SD = 4.48) and worse SQ (M = –13.74, SD = 4.32) compared with men (M = –12.68; SD = 4.03; Controlling for the main effects of gender did not alter the significance of the results.). Age negatively predicted NA (β = –4.97, p < .001), positively predicted PA (β = 5.95, p <

Table 1. Frequencies for the Full Sample on Gender, Race, Marital Status, and Income

	Number (%)
	Full sample
Gender[a]	
Female	340 (61.7%)
Male	211 (38.3%)
Race	
White	482 (87.5%)
African American	46 (8.3%)
Hispanic, Asian, or Other	23 (4.2%)
Marital status[b]	
Single	74 (13.5%)
Married	259 (47.4%)
Divorced	123 (22.5%)
Widowed	81 (14.8%)
Separated	9 (1.6%)
Education[c]	
Grade/middle school (Grades 1–9)	13 (2.4%)
High school	182 (33.1%)
Vocational education	30 (5.4%)
Some college	141 (25.6%)
College degree	103 (18.7%)
Post college professional degree	30 (5.4%)
Graduate, medical, or law degree	51 (9.3%)
Income[d]	
Less than $7,500	25 (4.6%)
$7,500–$14,999	72 (13.4%)
$15,000–$24,999	95 (17.7%)
$25,000–$39,999	119 (22.1%
$40,000–$74,999	139 (25.8%)
$75,000–$99,999	48 (8.9%)
More than $100,000	40 (7.4%)

Notes: NA = negative affect; PA = positive affect.

[a]Females reported greater stress compared with males ($t = -2.00$, $p = .046$) as well as worse sleep quality ($t = -2.87$, $p = .004$).

[b]Those who were married or widowed tended to have better sleep than those who were single, divorced, or separated ($F_{4,550} = 2.91$, $p = .021$).

[c]Those who had higher educations experienced better sleep ($F_{7,541} = 2.80$, $p = .007$; linear contrast test: $F = 16.10$, $p < .001$) and less stress ($F_{7,541} = 2.22$, $p = .031$; linear contrast test: $F = 11.67$, $p < .001$).

[d]Those with higher incomes experienced less NA ($F_{6,531} = 6.49$, $p < .001$; linear contrast test: $F = 31.95$, $p < .001$), greater PA ($F_{6,531} = 4.12$, $p < .001$; linear contrast test: $F = 22.34$, $p < .001$), less stress ($F_{6,531} = 9.99$, $p < .001$; linear contrast test: $F = 54.58$, $p < .001$), and better sleep ($F_{6,531} = 3.99$, $p < .001$; linear contrast test: $F = 11.55$, $p < .001$).

.001), negatively predicted stress ($\beta = -5.19$, $p < .001$), and positively predicted SQ ($\beta = 3.33$, $p < .001$).

The correlations between the variables are presented both between individuals, illustrating the global relationships between the variables, and within individuals, illustrating the daily relationships between the variables, in Table 3 (Zhang & Wang, 2014). These correlations are informative when comparing the strength of between-person findings to within-person findings, which we test later in the paper.

Effects of Stress and SQ on PA and NA

When PA was used as the dependent variable in Equation 1, age was associated with greater PA ($\gamma_{03} = 0.21$, $p < .001$). Better nightly SQ was related to higher PA within individuals ($\gamma_{20} = 0.26$, $p < .001$), and overall better SQ (mean effect) predicted greater PA between individuals ($\gamma_{01} = 0.67$, $p < .001$). The between-person effect was a significantly stronger predictor than the within person effect (γ_{01}–$\gamma_{20} = 0.42$, $p < .001$). High daily stress was associated with lower PA within individuals ($\gamma_{30} = -0.85$, $p < .001$), and high overall stress levels (mean effect) were associated with lower PA between individuals ($\gamma_{02} = -1.17$, $p < .001$). The between-person effect of stress was significantly more predictive of PA than the within-person effect (γ_{02}–$\gamma_{30} = -0.33$, $p < .001$). When the two-way interactions were added to the model, stress and age interacted ($\gamma_{31} = 0.01$, $p < .001$), revealing that greater than usual daily stress detrimentally affects PA more among midlife individuals. The results revealed a significant effect when the three-way interaction (Supplementary Figure 2) was included in the model ($\gamma_{41} = 0.001$, $p < .001$), illustrating that better SQ benefited PA more during times of low stress than high stress for midlife individuals but showed a greater buffering effect during times of high stress for older adults. A pseudo R^2 comparing the full model to a model without the intraindividual predictors revealed that 32% of the variation of PA was explained by the intraindividual predictors (Singer, 1998).

Considering the age effect on NA, higher age was associated with lower NA ($\gamma_{03} = -0.08$, $p < .001$). Better nightly SQ predicted lower NA ($\gamma_{20} = -0.03$, $p < .001$). High daily stress levels were associated with greater NA within individuals ($\gamma_{30} = 0.51$, $p < .001$), and high overall stress levels (mean effect) were associated with greater NA between individuals ($\gamma_{02} = 0.94$, $p < .001$). The between-person effect of stress was stronger than the within-person effect (γ_{02}–$\gamma_{30} = 0.42$, $p < .001$).

Table 2. Descriptive Statistics of the Person Means of the Variables

	N	Mean	*SD*	Median	Kurtosis	Skewness
NA	553	17.32	6.00	15.01	8.79	2.65
PA	553	45.35	10.24	45.37	−0.09	−0.13
Stress	560	18.21	4.41	18.16	0.57	0.58
SQ	559	−13.33	4.23	−13.46	−0.63	−0.18
Sleep time (min)	560	462	59.81	464	0.71	0.02

Note: NA = negative affect; PA = positive affect; SQ = sleep quality.

The two-way interactions illustrated that higher age (γ_{31} = –0.01, p < .001) and better nightly SQ buffered the effects of stress on NA (γ_{40} = –0.01, p < .001). The three-way interaction was not significant. The results of the final model are presented in Table 4. Pseudo R^2 comparing the full model from Equation 1 with NA as the dependent variable with the interindividual effects revealed that 52% of the within-person variance in NA was explained by the intraindividual predictors (Singer, 1998).

Moderation and Mediation of Stress, SQ, and PA on NA

The results of the main effects model demonstrate that lower age is associated with greater NA (γ_{03} = –0.08, p < .001). Within an individual, last night's SQ predicted lower daily NA today (γ_{20} = –0.03, p < .001). Overall better SQ (mean effect) predicted lower NA (γ_{01} = –0.10, p = .039). Greater daily stress was related to greater daily NA within individuals (γ_{30} = 0.51, p < .001) and between (mean effect) individuals (γ_{02} = 0.94, p < .001); the between-person effect was a stronger predictor (γ_{02}–γ_{30} = 0.42, p < .001). Higher daily PA was associated with lower NA within individuals (γ_{40} = –0.07, p < .001) but higher NA between persons (mean effect; γ_{03} = 0.08, p < .001).

When the two-way interactions were added to the models, higher age (γ_{31} = –0.01, p < .001) and high daily PA (γ_{41} = –0.02, p < .001) buffered the effects of high stress on NA. The three-way interactions illustrated cross-level

Table 3. Interindividual and Intraindividual Correlations

	N	Mean	*SD*	Minimum	Maximum
Interindividual correlations between variables averaged across the 56 days					
Stress and SQ	56	–0.35	0.04	–0.42	–0.26
PA and SQ	56	0.42	0.04	0.34	0.48
NA and SQ	56	–0.30	0.04	–0.39	–0.22
Stress and NA	56	0.66	0.04	0.57	0.76
PA and NA	56	–0.39	0.05	–0.53	–0.30
PA and stress	56	–0.59	0.03	–0.65	–0.51
Intraindividual correlations between variables averaged across the 552 participants					
Stress and SQ	544	–0.11	0.23	–1.00	0.84
PA and SQ	543	–0.20	0.24	–0.58	0.92
NA and SQ	536	–0.14	0.23	–0.85	0.86
Stress and NA	539	0.49	0.30	–0.67	0.98
PA and NA	542	–0.32	0.31	–0.92	0.77
PA and stress	547	–0.38	0.26	–1.00	0.76

Note: NA = negative affect; PA = positive affect; SQ = sleep quality. The intraindividual correlations resulted from taking the correlation for each individual across their 56 days and then averaging those correlations together. The interindividual correlations involved taking the correlations for each day and then averaging those correlations together.

Table 4. The Main and Interactive Effects of Age, Stress, and SQ, and on PA and NA

	Dependent variable: PA			Dependent variable: NA		
	Fixed effects	*SE*	*t* Value	Fixed effects	*SE*	*t* Value
Fixed within-effect estimates						
γ_{00} (Intercept)	45.84***	0.30	151.00	17.70***	0.20	89.68
γ_{10} (Time)	–0.02***	0.01	–3.35	–0.02***	0.003	–6.13
γ_{20} (SQ)	0.26***	0.02	15.90	–0.05***	0.01	–7.19
γ_{30} (Stress)	–0.84***	0.03	–31.28	0.58***	0.02	27.37
γ_{21} (Age*SQ)	–0.00	0.00	–0.29	0.00	0.001	1.56
γ_{31} (Age*Stress)	0.01***	0.003	4.54	–0.01***	0.002	–6.71
γ_{40} (SQ*Stress)	0.003	0.00	1.15	–0.01***	0.001	–5.44
γ_{41} (Age*SQ*Stress)	0.001***	0.01	3.79	0.00	0.00	1.39
Fixed between-effect estimates						
γ_{01} (SQ)	0.67***	0.08	8.17	–0.04***	0.05	–0.88
γ_{02} (Stress)	–1.17***	0.08	–14.69	0.85***	0.05	18.42
γ_{03} (Age)	0.22***	0.03	7.44	–0.10***	0.02	–5.79

Notes: NA = negative affect; PA = positive affect; SQ = sleep quality. The parameter estimates may be slightly different than those reported in text because these estimates reflect the final model.
***p < .001.

interactions between age, SQ, and stress (γ_{51} = 0.0005, p = .002) as well as age, SQ, and PA (γ_{61} = 0.0002, p = .005). Better SQ buffered the relationship between stress and NA more during times of low stress than high stress in older adults but equally mitigated the relationship between stress and NA regardless of stress levels for midlife adults (Supplementary Figure 3). Moreover, better SQ enhanced the effect of PA on NA in midlife adults, but better SQ buffered the association between low PA and NA in older adults (Supplementary Figure 4). Adding the four-way interaction to the model (γ_{81} = 0.00002, p = .037) revealed that in older adults PA buffered the relationship between high stress and NA, and better SQ enhanced the negative association between PA and NA more during times of low stress than high stress. In midlife adults, on the other hand, PA buffered the relationship between high stress and NA, and SQ enhanced this effect more during times of high stress compared with low stress (Supplementary Figure 5). The results of the final model are presented in Table 5. A pseudo R^2 revealed that 57% of the within-person variation of NA in Equation 2 was explained by the intraindividual effects (Singer, 1998).

A mediation test revealed that the interaction between daily stress and daily PA mediated the relationship between nightly SQ and daily stress on NA (Table 6).

Table 5. Main and Interactive Effects of Age, SQ, Stress, and PA on NA

	Estimate	*SE*	*t* Value
Fixed within-effect estimates			
γ_{00} (Intercept)	−4.60*	1.92	−2.39
γ_{10} (Time)	−0.02***	0.003	−6.42
γ_{20} (SQ)	−0.03***	0.01	−4.58
γ_{30} (Stress)	0.47***	0.02	26.05
γ_{40} (PA)	−0.07***	0.01	−9.55
γ_{21} (Age*SQ)	0.00	0.00	1.91
γ_{31} (Age*Stress)	−0.01***	0.002	−6.98
γ_{41} (Age*PA)	0.00	0.00	1.34
γ_{50} (SQ*Stress)	0.00	0.86	0.39
γ_{60} (SQ*PA)	0.00	0.00	0.33
γ_{70} (Stress*PA)	−0.02***	0.001	−27.24
γ_{51} (Age*SQ*Stress)	0.001***	0.0002	3.54
γ_{61} (Age*SQ*PA)	0.0002*	0.0001	2.49
γ_{71} (Age*Stress*PA)	−0.00	0.00	−1.39
γ_{80} (SQ*Stress*PA)	0.00	0.00	1.75
γ_{81} (Age*SQ* Stress*PA)	−0.00002*	0.00001	2.08
Fixed between-effect estimates			
γ_{01} (SQ)	−0.10***	0.05	−2.08
γ_{02} (Stress)	0.94***	0.05	17.70
γ_{03} (PA)	0.08***	0.02	3.55
γ_{04} (Age)	−0.04***	0.02	−2.50

Notes: NA = negative affect; PA = positive affect; SQ = sleep quality. The parameter estimates may be slightly different than those reported in text because these estimates reflect the final model.
*p < .05. ***p < .001.

Table 6. Testing the Mediation of the Interaction Between PA and Stress on the Relationship Between Sleep and Stress on NA

Sleep*Stress on PA*Stress (path a)	0.496 (.012) p < .001
PA*Stress on NA (path b)	−0.018 (.001) p < .001
Sleep*Stress on NA (path c) without PA	−0.008; p < .001
Sleep*Stress on NA (path c′) with PA	−0.000; p = .785

Note: NA = negative affect; PA = positive affect. Sobel = −23.20, p < .001.

Discussion

Our results add strength to findings that illustrate the relationships between SQ and stress (e.g., Åkerstedt et al., 2012; McEwen, 2006) as well as SQ and affect (e.g., Bower et al., 2010; Gujar, et al., 2010; Walker & Tharani, 2009). Although we show that global levels of SQ, stress, and PA relate to daily NA, we further illustrate these relationships within individuals at the daily level. By using a process-oriented approach in which each individual serves as their own control, we see that relationships between SQ, stress, and affect are best understood in terms of the associations at both day-to-day level and overall levels. These findings emphasize the importance of considering idiographic, not just nomothetic, approaches (Molenaar, 2004), in understanding the role of SQ and PA in the stress–NA relationship.

The between-person effects illustrate that global individual differences in SQ and stress relate to PA and NA. Moreover, stress differences between individuals were more strongly associated with PA and NA than fluctuations within individuals, and the effect of sleeping better than others was more strongly associated with PA than the effect of having one night of better than usual sleep. Although these findings indicate that individual differences in stress and SQ are more strongly associated with affect than daily fluctuations in these constructs, adding the within-person effects to the models explained a substantial amount of the variance. Specifically, the results reveal that SQ and PA may be two contextual factors that associated with stress reactivity. Because the within-person daily stress–NA relationship predicts emotional and physical health (Charles et al., 2013; Piazza et al., 2013), the strength of these within-person effects suggests that targeting daily SQ and PA as a way to unlink the relationship between stress and NA in intervention and prevention strategies can benefit and protect emotional well-being.

Addressing the first aim, better nightly SQ buffered the relationship between high daily stress and low daily PA in older adults. In midlife adults, however, SQ showed a greater buffering effect on PA when the individual experienced low daily stress. The descriptive statistics depicting midlife adults as perceiving more severe stress than older adults corroborate findings illustrating that midlife adults experience greater stress (Lachman, 2004). Therefore, it is possible that one better night of sleep cannot buffer

the detrimental effects of high next day stress on PA, and midlife adults may need to accumulate multiple nights of better sleep to experience the buffering impact of sleep on the relationship between high stress and PA. Future research should explore this possibility.

When NA was used as the dependent variable in the first set of analyses, better nightly sleep buffered the impact of daily stress on daily NA. Interestingly, when PA was included as a predictor in the second set of analyses, nightly SQ equally reduced the impact of daily stress on NA in midlife adults, regardless of stress levels. In older adults, however, nightly SQ showed greater benefits to NA during times of low stress. The meditational analyses reveal that the moderating relationship between PA and stress mediates the moderating relationship between sleep and stress on NA. These findings illustrate that the relationship between daily PA and stress accounts for some of the benefits of nightly SQ on the relationship between daily stress and daily NA.

The results regarding the second aim reveal that daily PA buffers the impact of daily stress on NA. This finding supports Fredrickson's (2004) *Broaden and Build Theory* at the microlevel, suggesting that positive emotions undo the effects of stress on NA on a day-to-day basis. The three-way interaction between age, nightly SQ, and daily PA illustrates that better nightly sleep in midlife adults enhanced the benefits of daily PA on daily NA, but better nightly sleep in older adults buffered the impact of low daily PA on daily NA. Therefore, obtaining better sleep in midlife may be one way to reap the most protective benefits from positive emotions, whereas obtaining better SQ in later life protects against the detrimental effects of low PA. Because older adults place greater emphasis on emotional regulation and are more responsive to positive material (Carstensen & Mikels, 2005), it may be PA protects against NA, and good sleep bolsters that PA for older adults, whereas midlife individuals may need good sleep to reap greater benefits from PA.

Finally, the results of the four-way interaction between age, daily stress, nightly SQ, and daily PA suggest that the relationship between daily stress and daily NA depends on daily fluctuations between both PA and SQ, but further illustrate that these relationships differ depending on age. In midlife adults, daily PA buffered the relationship between high daily stress and daily NA, and better nightly sleep equally enhanced the inverse relationship between PA and NA regardless of next day stress. For example, an individual experiencing high amounts of PA was less affected by stress than an individual with low amounts of PA. Within individual levels of PA, better sleep lessened the association between stress and NA even more. Among older adults, SQ enhanced the effect of PA, but this enhancement unexpectedly differed depending on stress levels. Specifically, last night's better sleep buffered the impact of low stress more than high stress the next day.

The study is limited in that it does not account for the possible physiological, cognitive, or interpersonal changes associated with aging, which in turn may affect SQ and explain the age differences in the intraindividual variability between sleep, stress, and affect. Furthermore, although the sample is representative of the Northern Indiana region from which it was taken, it is racially/ethnically homogenous. It is unclear whether within-person fluctuations differ across ethnicities, so the findings may not hold across all groups. Finally, the study uses self-reported indicators of SQ, but other measures, such as actigraphy or polysomnography, could capture more objective dimensions of SQ and would be an important area for future research.

The results illustrating the relationship between PA and stress as an effective mediator on the relationship between stress and sleep on NA are consistent with global trends wherein SQ mitigates stress and promotes positive emotions, and these positive emotions undo the detrimental effects of stress (Fredrickson, 2004). Although we see evident relationships between SQ, stress, and affect at the daily level, this study does not test the causal chain of events between these constructs. Future research is needed to explore the possible reciprocal relationships between the constructs and conduct longitudinal lagged mediation analyses to better sort out the mechanisms by which these constructs interact and relate to one another.

The large sample size and 56 days of data add strength to our findings. Recognizing that between-person findings cannot be applied to the within-person level (Brose et al., 2010; Molenaar, 2004; Molenaar & Campbell, 2009), the current study adds to the literature by examining the relationships between SQ, stress, and affect in a microlevel, prospective way. The results revealed that daily increases in stress and decreases in SQ detrimentally affect PA and NA, similar to cross-sectional research illustrating a detrimental impact of poor global SQ and high global stress on affect (Bower et al., 2010; Cunningham et al., 2014; Gujar et al., 2010; Walker, 2009; Walker & Tharani, 2009). The moderating role of age further suggests that the relationships between SQ, stress, and affect differ depending on developmental phase, highlighting the need to consider multiple contextual factors when examining these developmental processes. Studying these relationships with an idiographic perspective shows how these processes change and interact with each other for any one individual in real time and how contextual factors (such as age) affect these daily relationships.

Supplementary Material

Supplementary material can be found at: http://psychsocgerontology.oxfordjournals.org/

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