

# The Importance of Physical Activity and Sleep for Affect on Stressful Days: Two Intensive Longitudinal Studies

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We investigated the potential stress-buffering effect of 3 health behaviors—physical activity, sleep quality, and snacking—on affect in the context of everyday life in young adults. In 2 intensive longitudinal studies with up to 65 assessment days over an entire academic year, students (Study 1,  $N = 292$ ; Study 2,  $N = 304$ ) reported stress intensity, sleep quality, physical activity, snacking, and positive and negative affect. Data were analyzed using multilevel regression analyses. Stress and positive affect were negatively associated; stress and negative affect were positively associated. The more physically active than usual a person was on a given day, the weaker the association between stress and positive affect (Study 1) and negative affect (Studies 1 and 2). The better than usual a person's sleep quality had been during the previous night, the weaker the association between stress and positive affect (Studies 1 and 2) and negative affect (Study 2). The association between daily stress and positive or negative affect did not differ as a function of daily snacking (Studies 1 and 2). On stressful days, increasing physical activity or ensuring high sleep quality may buffer adverse effects of stress on affect in young adults. These findings suggest potential targets for health-promotion and stress-prevention programs, which could help reduce the negative impact of stress in young adults.

**Keywords:** physical activity, sleep quality, snacking, everyday stress, positive and negative affect

Nearly everyone encounters stressors in daily life, such as being late for a meeting, work deadlines, or a disagreement with a significant other. These daily stressors can have a strong impact on daily affect (Jacobs et al., 2007; O'Hara, Armeli, Boynton, & Tennen, 2014), well-being (Almeida, 2005), or mental health, sometimes even more than major life events (DeLongis, Coyne, Dakof, Folkman, & Lazarus, 1982; Thoits, 2010). Identifying behaviors that may help people reduce the adverse effects of everyday stress is of considerable importance.

One resource that has been thought to buffer stress is physical activity. Experimental studies have shown that the association between stress—either assessed as a stressful event (Norris, Carroll, & Cochrane, 1992; Roth & Holmes, 1987) or induced through a stressful task (Childs & de Wit, 2014; Mata, Hogan, Joormann, Waugh, & Gotlib, 2013; Rejeski, Thompson, Brubaker, & Miller, 1992; Rimele et al., 2007)—and depressive symptoms was weaker in group of physically active subjects than a control group. Cross-sectional research (Ensel & Lin, 2004; Roth & Holmes, 1985) and one longitudinal study (Klaperski, Seelig, & Fuchs, 2012) showed that the association between increased stress and increased depressive symptoms was weaker for more physically active than for less physically active employees and young adults. However, this finding could not be replicated in adolescents (Moksnes, Moljord, Espnes, & Byrne, 2010).

Existing studies have mainly tested the stress-buffering role of physical activity on depressive symptoms, focusing on differences between individuals. This between-person perspective, however, offers only a snapshot of a person's behavior and well-being as a stable trait. Daily stress, especially, varies greatly within the same person over time, which cannot be captured by cross-sectional or experimental between-person studies. These between-person associations may be different from associations on the within-person level (Molenaar, 2004). Hence, how stress, physical activity, and affect unfold within a person in the context of everyday life is unclear. Although Klaperski et al.'s (2012) results were based on longitudinal data, they could not fully expose everyday life variability, as the two assessment points were 10 months apart.

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Given that the longitudinal data that support the health-protective association between habitual physical activity and well-being during stressful times (Klaperski et al., 2012) are limited, it is unknown whether health behaviors such as sleep quality or snacking could also serve as stress buffers. Previous research showed that day-to-day health behaviors such as sleep duration (Wrzus, Wagner, & Riediger, 2014) and sleep quality (Flueckiger, Lieb, Meyer, & Mata, 2014; Galambos, Dalton, & Maggs, 2009) were associated with increased positive and decreased negative affect. Snacking was associated with pleasurable emotions (Desmet & Schifferstein, 2008) and increased positive affect in an experimental setting (Benton, Slater, & Donohoe, 2001), as well as in everyday life with controlled snack administration (Macht & Dettmer, 2006). However, some experimental research has shown that snacking can also be followed by guilt (Macht & Dettmer, 2006; Steenhuis, 2009) and reduced positive affect (Hormes & Rozin, 2011). Hence, it is unclear whether snacking has a stress-buffering or detrimental effect on affect during stressful times, whereas prior research has supported a positive association between sleep quality and affect, indicating a potential stress-buffering effect of sleep quality.

It is important to note that it is an ongoing debate whether snacking is a health-enhancing or health-deteriorating behavior, for example, in the context of overweight and obesity (Bertéus Forslund, Torgerson, Sjöström, & Lindroos, 2005; Keast, Nicklas, & O'Neil, 2010). In this manuscript, we consider snacking to be a health behavior that, like others (e.g., physical activity, sleep), can be performed in a health-enhancing or health-deteriorating way.

Positive and negative affect may change from day to day (Roecke, 2006) and may therefore be sensitive to changes in daily life. Positive affect has been associated with various life outcomes such as health, success (Lyubomirsky, King, & Diener, 2005), and reduced mortality (Chida & Steptoe, 2008), underlining the potential benefit of regulating positive affect in everyday life for long-term outcomes. (For a review, see Houben, van den Noortgate, & Kuppens, 2015.) Notably, health behaviors also tend to vary in daily life. Thus, health behaviors are quite unlike stable between-person characteristics that have been identified as potential stress buffers, such as self-esteem or social support (Delongis, Folkman, & Lazarus, 1988).

### Hypotheses

On the basis of this rationale, we used two intensive longitudinal studies over an entire academic year to identify health behaviors that might help young adults sustain high positive and low negative affect on stressful days. We sought to examine the impact of three health behaviors—physical activity, sleep quality, and snacking—on the association between stress and positive as well as negative affect in everyday life. Specifically, we hypothesized the following.

*Hypothesis 1:* On days on which participants report experiencing higher stress than usual, they will also report lower positive affect and higher negative affect.

*Hypothesis 2a:* The more physically active than usual a person is on a given day, the weaker the association will be between stress and affect.

*Hypothesis 2b:* The better than usual a person's sleep quality was during the previous night, the weaker the association will be between stress and affect.

Concerning the effect of snacking on affect, some studies have suggested higher positive affect after snacking (e.g., Desmet & Schifferstein, 2008), whereas others have shown increased negative affect after snacking (e.g., Steenhuis, 2009). Given these contradictory findings, we examined the following two competing hypotheses for the association between affect and stress, as a function of snacking amount.

*Hypothesis 2c<sub>1</sub>:* The more snacking than usual a person reports on a given day, the *weaker* the association between stress and affect will be.

*Hypothesis 2c<sub>2</sub>:* The more snacking than usual a person reports on a given day, the *stronger* the association between stress and affect will be.

Important to note for Hypotheses 2a–2c<sub>2</sub>, we predicted a *negative* association between stress and positive affect and a *positive* association between stress and negative affect.

### Method

#### Study 1

**Design and procedure.** Data were obtained from an intensive longitudinal survey of first-year students at the University of Basel, Switzerland from November, 2011 to July, 2012. Participants were recruited through announcements made during introductory lectures that are obligatory for first-year students majoring in law, natural sciences, or psychology. Interested students provided their e-mail addresses and received an e-mail with a link to an online entry assessment. Detailed information about the study was provided on the first page of the entry assessment. After giving informed consent, the students were invited to participate in 61 short online assessments, each taking, on average, 5.3 min ( $SD = 1.38$ ) to complete. For the first 28 assessments, an invitation was mailed every 6 days. This 6-day interval during the first half of the academic year was chosen to cover all weekdays about equally often, keep participants' burden acceptable, and consequently minimize study drop out. The remaining 33 assessment invitations were sent out on consecutive days to get a better snapshot of daily variability of affect, stress, and health behaviors. Finally, participants completed an online exit assessment.

In each assessment, each participant provided his or her personal code. This code was used to link individual participants' completed online assessments. Participants were never asked to provide any information that would allow them to be identified; personal codes could not be linked to e-mail addresses.

In addition, participants were invited to a 3-hr laboratory session. As the aim of this article was to elucidate the day-to-day associations between health behaviors, stress, and affect, the laboratory between-person data were not considered in the present analyses.

All participants received compensation for their participation. Psychology students could choose between financial compensation, equivalent course credit, or a mix of both. The local ethics committee, Ethikkommission beider Basel, Switzerland, approved the study (reference number EK: 48/11).

**Participants.** A total of 323 participants answered the daily online assessments. Of these, 31 (10%) were excluded from the analyses because they completed only three or fewer online as-

assessments, not allowing statistical analyses on cubic temporal associations. Thus, the final sample was  $N = 292$ . The 292 participants provided a total of 11,050 responses over the 61 assessments; on average, each participant completed 38 assessments ( $SD = 18$ ; range = 4–61), which reflects a compliance rate of 62% (range: 7–100%). To test for systematic differences between participants with high and low compliance, we compared participants with compliance rates of 50% or higher (this means, that participants completed at least 50% of the surveys;  $n = 179$ ) to those with lower compliance rates (participants completed less than 50% of the surveys;  $n = 113$ ) and found no differences between the groups concerning extroversion ( $M = 22.22$ ,  $SD = 3.49$  vs.  $M = 21.81$ ,  $SD = 4.40$ ),  $t(64.16) = -0.57$ ,  $p = .571$ ; neuroticism ( $M = 19.90$ ,  $SD = 4.33$  vs.  $M = 19.72$ ,  $SD = 4.73$ ),  $t(67.99) = 2.31$ ,  $p = .022$ ; or conscientiousness ( $M = 24.68$ ,  $SD = 3.25$  vs.  $M = 24.06$ ,  $SD = 3.70$ ),  $t(67.40) = -1.00$ ,  $p = .321$ . However, participants in the lower compliance group reported higher levels of experienced stress during the study ( $M = 0.57$ ,  $SD = 0.57$  vs.  $M = 0.68$ ,  $SD = 0.58$ ),  $t(239.33) = 2.31$ ,  $p = .022$ .

First-year university students were a particularly suitable population to test our hypotheses. First, they experience comparable amounts of stressful (e.g., examination periods) and nonstressful (e.g., vacation periods) times. They are thus in a natural, but relatively controlled, setting. Second, most students are of similar educational background and age; hence, they represent a relatively homogeneous population. Third, all university students have Internet access through their university; therefore, online assessment does not introduce a selection bias.

Because within-person analyses focus on associations within the same person—in our case, comparing individual reports across the days of the study period—we did not control for gender or other between-person variables as variables of interest. However, it is possible that within-person associations differ between men and women and go in opposite directions, and thus we also analyzed moderation effects with respect to gender (three-way interactions).

## Measures.

**Entry questionnaire.** Sociodemographic information was obtained during the entry assessment.

**Day-level questionnaire.** Stress was measured by asking participants in an open-question format whether they had experienced a stressful event in the last 24 hr. If yes, they were asked to indicate what kind of stressor they had experienced and how stressful this event was on a 5-point Likert scale from 1 (*a little stressful*) to 5 (*very stressful*). They could report up to three stressful events in the morning, afternoon, and evening. If participants had experienced no stressful event in the last 24 hr, they skipped this question and the answer was treated as 0 in the analyses. The stress intensity score was calculated as the mean intensity of all stressful events on a given day.

**Godin Leisure-Time Exercise Questionnaire.** Physical activity was evaluated with the Godin Leisure-Time Exercise Questionnaire (Godin & Shephard, 1985), adapted to the daily online questionnaire format (see Mata et al., 2012). Participants were asked to indicate the number of minutes engaged in mild (minimal effort; e.g., easy walking), moderate (not exhausting; e.g., fast walking), and strenuous exercise (heart beats rapidly; e.g., running) within the last 24 hr. The daily minutes of each level of physical activity were weighted by metabolic equivalents and

summed to a total daily leisure-activity score. High scores reflect high levels of physical activity (Godin & Shephard, 1985). The original Godin Leisure-Time Exercise Questionnaire showed adequate concurrent validity with maximum oxygen consumption (Jacobs, Ainsworth, Hartman, & Leon, 1993).

**Pittsburgh Sleep Quality Index.** Sleep quality was assessed with the item from the German version of the Pittsburgh Sleep Quality Index (Riemann & Backhaus, 1996) that shows the highest correlation with the final score of the full scale (single item—total correlation),  $r = .83$  (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989). Participants indicated their sleep quality during the previous night on a 5-point Likert scale from 1 (*very bad*) to 5 (*very good*).

**Snacking.** Snacking was characterized as every food intake outside main meals. Participants reported the number of high-fat sweet snacks (e.g., chocolate, ice cream), high-fat savory snacks (e.g., chips, pizza), low-fat savory snacks (e.g., bread, pretzel), and other snacks. The numbers of each snack category were then summed to a daily snacking score.

**Positive and negative affect.** Affect was assessed with the German version of the Pleasantness Scale (Roedcke, 2006), a six-item instrument whose results have been shown to be comparable to those of the Positive and Negative Affect Schedule (Watson, Clark, & Tellegen, 1988) in a nonclinical sample (Roedcke, 2006). Participants rated on a 7-point Likert scale from 1 (*not at all*) to 7 (*extremely*) the extent to which they had felt each of the following emotions in the last 24 hr: happy, content, cheerful, sad, downhearted, and frustrated. Cronbach's internal consistency reliability was  $\alpha = .94$  ( $M = 14.54$ ,  $SD = 4.18$ ) for positive affect on the within-person level and  $\alpha = .97$  ( $M = 14.54$ ,  $SD = 4.18$ ) on the between-person level. For negative affect, internal consistency reliability was  $\alpha = .85$  ( $M = 7.00$ ,  $SD = 3.96$ ) on the within-person level and  $\alpha = .93$  ( $M = 7.00$ ,  $SD = 3.96$ ) on the between-person level.

## Statistical Analyses

As repeated measurement points were nested within participants, data were analyzed using multilevel regression analyses. This method allows testing the within-person association between daily health behaviors, daily stress, and daily affect, as well as appropriately handling missing data and varying time intervals (Raudenbush & Bryk, 2002). Predictor variables were centered around each individual's mean, allowing us to test whether deviations from, for example, an individual's average physical activity were associated with positive affect on that day. Person-mean centering additionally reduces the impact of multicollinearity between moderator and predictor (Tabachnick & Fidell, 2013), which can rarely be avoided entirely (Kraemer & Blasey, 2004).

Multilevel regression analyses were conducted for each predictor separately (physical activity, sleep quality, and snacking) and for each outcome (positive and negative affect). Our model contained as fixed effects stress as predictor, the respective health behavior as moderator, and the interaction between the two. Due to the symmetry of the interaction term, the distinction between predictor and moderator is arbitrary (Preacher, Curran, & Bauer, 2006). To account for potential nonlinear trends of affect over time, we also included a temporal trend represented as linear, quadratic, and cubic terms in the model. Including these terms improved fit in all models. We used a random slopes model in which intercept and the slopes of time and moderator were allowed to vary between individuals. As physical activity, snacking,

negative affect, and stress were not normally distributed, we conducted logarithmic transformations for physical activity and stress and square-root transformations for snacking and negative affect to approximate normal distributions. The software R (version 2.15.1) was used for all analyses and the package nlme (Pinheiro, Bates, DebRoy, Sarkar, & R Core Team, 2015) was applied for all multilevel analyses.

## Study 2

**Design and procedure.** Study 2 was an extension of Study 1. The data were obtained between October 2012 and July 2013. Participants were recruited through flyers and announcements made during lectures in several departments. After receiving detailed information about the study and giving informed consent, participants were invited to 65 short online assessments, each taking, on average, 5.38 min ( $SD = 1.23$ ) to complete. For the first 35 assessments, an invitation was sent out every 6 days; the following 30 were sent on consecutive days. In addition, participants were invited to a laboratory session that included 10 min in which they could eat a variety of snacks (high-fat sweet, high-fat savory, low-fat savory) ad libitum; a subsample of participants wore actigraph watches for 1 week, measuring sleep and physical activity behaviors.

**Participants.** A total of 337 first-year university students took part. Of these, 33 (10%) were excluded because they completed only three or fewer daily assessments, not allowing statistical analyses on cubic temporal associations. Thus, the final sample was  $N = 304$ . These participants provided 11,857 responses over the 65 assessments; on average, each participant completed 39 assessments ( $SD = 19$ ; range = 4–65), representing a compliance rate of 60% (range = 6–100%). As in Study 1, we tested for systematic differences between participants with high and low compliance and again found no differences concerning extroversion ( $M = 28.93$ ,  $SD = 6.21$  vs.  $M = 27.80$ ,  $SD = 6.61$ ),  $t(87.71) = -1.08$ ,  $p = .285$ , or neuroticism ( $M = 20.13$ ,  $SD = 7.85$  vs.  $M = 21.75$ ,  $SD = 7.05$ ),  $t(96.41) = 1.34$ ,  $p = .182$ , in participants with compliance rates of 50% or higher ( $n = 187$ ) compared with those with lower compliance rates ( $n = 117$ ). We found that participants with higher compliance rates reported higher conscientiousness ( $M = 31.92$ ,  $SD = 6.92$  vs.  $M = 29.03$ ,  $SD = 8.09$ ),  $t(90.07) = -2.49$ ,  $p = .002$ , and—as in Study 1—experienced lower levels of stress during the study ( $M = 0.65$ ,  $SD = 0.39$  vs.  $M = 0.79$ ,  $SD = 0.39$ ),  $t(245.72) = 3.71$ ,  $p < .001$ .

**Measures.** All measures used are listed below. For measures already described for Study 1 above, only reliability is reported.

**Entry questionnaire.** Sociodemographic information was obtained in the entry assessment.

**Day-level questionnaire.** Sleep quality, physical activity, snacking, and positive and negative affect were assessed with the same scales as in Study 1. Cronbach's internal consistency reliability was  $\alpha = .92$  ( $M = 14.53$ ,  $SD = 4.06$ ) for positive affect on the within-person level and  $\alpha = .97$  ( $M = 14.53$ ,  $SD = 4.06$ ) on the between-person level;  $\alpha = .85$  ( $M = 6.59$ ,  $SD = 3.83$ ) for negative affect on the within-person level and  $\alpha = .93$  ( $M = 6.59$ ,  $SD = 3.83$ ) on the between-person level. In addition to the procedures used in Study 1, self-reported data were validated using behavioral data: Average self-reported snacking over the 65 assessment days was associated with behaviorally measured snack intake assessed in the laboratory session (high-fat sweet snacks:  $r = .25$ ,  $p = .002$ ; high-fat savory snacks:  $r = .31$ ,  $p < .001$ ;

low-fat savory snacks:  $r = .28$ ,  $p < .001$ ). Self-reported sleep duration and physical activity were associated with sleep duration ( $\beta = 0.75$ ,  $SE = 0.04$ ,  $p < .001$ ) and physical activity ( $\beta = 0.18$ ,  $SE = 0.06$ ,  $p = .003$ ) measured by actigraph watches worn for 7 consecutive days (for more details see Flueckiger, Lieb, Meyer, Witthauer, & Mata, 2015).

Stress was assessed by asking participants whether they had experienced stressful events in the last 24 hr and having them rate the experience of any such events on a 6-point Likert scale from 0 (*not experienced*) to 5 (*very stressful*). If participants experienced stressful events, they were asked to select one of five categories to describe them: interpersonal (e.g., argument with partner, family problem), study/work-related (e.g., difficult task, late for meeting), ego threatening (e.g., examination, job interview), health-related (e.g., sickness, tiredness), and other (e.g., computer problems, shopping; cf. O'Connor, Jones, Conner, McMillan, & Ferguson, 2008). For each category, participants could indicate up to two stressful events. Stress intensity was calculated as the mean intensity of all stressful events reported on a given day.

**Statistical analyses.** The same multilevel regression analyses as reported for Study 1 were used.

## Results

### Participant Characteristics

Sample characteristics are displayed in Table 1. The proportion of female participants was high in both studies. There was considerable variability in reported physical activity in both studies. Participants reported relatively high sleep quality, a medium amount of snacking, average positive affect, and relatively low negative affect in both studies. Stress ratings in Study 2 were almost twice as high as in Study 1.

### Main Results

Results for positive affect in Studies 1 and 2 are presented in Table 2 and for negative affect in Table 3. Consistent with Hypothesis 1, both studies showed that on days on which participants reported more stress than usual, they also reported decreased

Table 1  
Sample Characteristics

| Characteristic                  | Study 1 ( $N = 292$ ) | Study 2 ( $N = 304$ ) |
|---------------------------------|-----------------------|-----------------------|
| Gender (% women)                | 75.0%                 | 64.1%                 |
| Mean age ( $SD$ )               | 20.7 (2.5)            | 21.4 (5.1)            |
| Mean stress ( $SD$ )            | .6 (.6)               | 1.1 (.9)              |
| Mean physical activity ( $SD$ ) | 368.1 (464.3)         | 422.5 (515.1)         |
| Mean sleep quality ( $SD$ )     | 3.6 (1.0)             | 3.6 (1.0)             |
| Mean snacking ( $SD$ )          | 2.2 (2.2)             | 2.3 (2.2)             |
| Mean positive affect ( $SD$ )   | 4.9 (1.4)             | 4.9 (1.4)             |
| Mean negative affect ( $SD$ )   | 2.3 (1.3)             | 2.2 (1.3)             |

*Note.* Sleep quality was rated on a 5-point Likert scale from 1 (*very bad*) to 5 (*very good*). Minutes of mild, moderate, and strenuous physical activity were converted into metabolic equivalents. In Study 1, stress was rated on a 5-point Likert scale from 1 (*a little stress*) to 5 (*very stressful*) and in Study 2 on a 6-point Likert scale from 0 (*not experienced*) to 5 (*very stressful*). Positive and negative affect results represent 6 emotions rated on a 7-point Likert scale from 1 (*not at all*) to 7 (*extremely*).

Table 2

*Results of the Multilevel Regression Analyses Predicting Positive Affect for Studies 1 and 2*

| Outcome                    | Study 1                |                        |                  |                | Study 2                |                        |                   |                |
|----------------------------|------------------------|------------------------|------------------|----------------|------------------------|------------------------|-------------------|----------------|
|                            | <i>B</i> ( <i>SE</i> ) | <i>t</i> ( <i>df</i> ) | 95% CI           | <i>p</i> value | <i>B</i> ( <i>SE</i> ) | <i>t</i> ( <i>df</i> ) | 95% CI            | <i>p</i> value |
| <b>Model 1</b>             |                        |                        |                  |                |                        |                        |                   |                |
| Stress                     | −10.63 (.61)           | −17.58 (10752)         | [−11.82, −9.45]* | <.001          | −13.00 (.57)           | −22.85 (11547)         | [−14.11, −11.85]* | <.001          |
| Physical activity          | .57 (.05)              | 11.72 (10752)          | [.47, .66]*      | <.001          | .65 (.05)              | 12.76 (11547)          | [.55, .75]*       | <.001          |
| Stress × Physical Activity | .54 (.20)              | 2.71 (10752)           | [.15, .93]*      | .007           | .36 (.19)              | 1.91 (11547)           | [−.01, .73]       | .057           |
| <b>Model 2</b>             |                        |                        |                  |                |                        |                        |                   |                |
| Stress                     | −9.48 (.59)            | −15.99 (10733)         | [−10.64, −8.32]* | <.001          | −12.13 (.57)           | −21.18 (11477)         | [−13.25, −11.01]* | <.001          |
| Sleep quality              | 1.78 (.11)             | 15.60 (10733)          | [1.56, 2.00]*    | <.001          | 1.30 (.11)             | 11.97 (11477)          | [1.09, 1.52]*     | <.001          |
| Stress × Sleep Quality     | 1.46 (.44)             | 3.32 (10733)           | [.60, 2.31]*     | .001           | .91 (.40)              | 2.27 (11477)           | [.12, 1.70]*      | .024           |
| <b>Model 3</b>             |                        |                        |                  |                |                        |                        |                   |                |
| Stress                     | −10.46 (.61)           | −17.22 (10751)         | [−11.66, −9.27]* | <.001          | −13.15 (.57)           | −13.15 (11522)         | [−14.27, −12.02]* | <.001          |
| Snacking                   | .57 (.16)              | 3.62 (10751)           | [.26, .88]*      | <.001          | .46 (.15)              | 3.04 (11522)           | [.16, .75]*       | .002           |
| Stress × Snacking          | .62 (.62)              | 1.00 (10751)           | [−.60, 1.84]     | .316           | .07 (.54)              | .13 (11522)            | [−1.00, 1.13]     | .90            |

*Note.* Estimates of the main effects can be interpreted as predictors being person-mean centered. Positive and negative affect were multiplied by 10 in order to obtain more significant digits. Interaction terms can be interpreted as follows: For example, if the moderator sleep quality increases one unit, the slope between stress and positive affect increases by 1.46 units.

\*  $p < .05$ .

positive affect and increased negative affect. It should be noted that these main effects are conditional on all other variables in the analyses being fixed at participants' personal means. For example, the finding that on days on which participants reported more stress than usual, they also reported that decreased positive affect should be interpreted as "on days on which participants reported more stress than usual, and an average level of physical activity (or sleep quality, or snacking), they also reported decreased positive affect." Because predictors were person-mean centered, main effects can be interpreted in the presence of the interaction term. Thus, the coefficient indicates the slope for the association between stress and affect when the moderator is equal to zero (personal mean). Nevertheless, we also analyzed the main effects without including the interaction term, which led to comparable results.

Next, we analyzed whether physical activity, sleep quality, or snacking moderated the relation between stress and affect (Hypotheses 2a–c<sub>2</sub>). Figure 1 shows the interaction between health behaviors and stress on positive and negative affect for Studies 1

and 2. For a clearer graphic representation of the results, the 5th and 95th percentiles for physical activity, sleep quality, and snacking were chosen for illustrative purposes. Concerning Hypothesis 2a, in Study 1, the negative association between stress and positive affect was weaker the more physically active than usual a person was that day. Study 2 showed a similar pattern, but the interaction between physical activity and stress on positive affect was short of being significant, 95% CI [−0.01, 0.73],  $p = .057$ . In both studies, the positive association between stress and negative affect was weaker the more physically active than usual a person was that day.

In line with Hypothesis 2b, the better a person's sleep quality during the previous night was, the weaker the association between stress and affect. Specifically, the negative association between stress and positive affect was weaker the better a person's sleep quality, as was the negative association between stress and negative affect (only Study 2). Sleep quality did not moderate the association between stress and negative affect in Study 1.

Table 3

*Results of the Multilevel Regression Analyses Predicting Negative Affect for Studies 1 and 2*

| Outcome                    | Study 1                |                        |               |                | Study 2                |                        |               |                |
|----------------------------|------------------------|------------------------|---------------|----------------|------------------------|------------------------|---------------|----------------|
|                            | <i>B</i> ( <i>SE</i> ) | <i>t</i> ( <i>df</i> ) | 95% CI        | <i>p</i> value | <i>B</i> ( <i>SE</i> ) | <i>t</i> ( <i>df</i> ) | 95% CI        | <i>p</i> value |
| <b>Model 1</b>             |                        |                        |               |                |                        |                        |               |                |
| Stress                     | 3.80 (.17)             | 22.06 (10716)          | [3.46, 4.13]* | <.001          | 4.80 (.17)             | 28.78 (11533)          | [4.48, 5.13]* | <.001          |
| Physical activity          | −.11 (.02)             | −7.03 (10716)          | [−.13, −.08]* | <.001          | −.10 (.02)             | −6.55 (11533)          | [−.13, −.07]* | <.001          |
| Stress × Physical Activity | −.13 (.06)             | −2.07 (10716)          | [−.25, −.01]* | .038           | −.15 (.06)             | −2.67 (11533)          | [−.26, −.04]* | .008           |
| <b>Model 2</b>             |                        |                        |               |                |                        |                        |               |                |
| Stress                     | 3.47 (.17)             | 20.58 (10697)          | [3.14, 3.80]* | <.001          | 4.56 (.17)             | 27.51 (11463)          | [4.23, 4.88]* | <.001          |
| Sleep quality              | −.54 (.03)             | −15.43 (10697)         | [−.61, −.47]* | <.001          | −.37 (.03)             | −11.40 (11463)         | [−.43, −.30]* | <.001          |
| Stress × Sleep Quality     | −.14 (.13)             | −1.01 (10697)          | [−.40, .13]   | .313           | −.33 (.12)             | −2.81 (11463)          | [−.57, −.10]* | .005           |
| <b>Model 3</b>             |                        |                        |               |                |                        |                        |               |                |
| Stress                     | 3.77 (.17)             | 21.73 (10715)          | [3.43, 4.11]* | <.001          | 4.83 (.17)             | 28.85 (11508)          | [4.50, 5.16]* | <.001          |
| Snacking                   | −.08 (.05)             | −1.75 (10715)          | [−.18, .01]   | .079           | −.01 (.04)             | −.20 (11508)           | [−.10, .08]   | .840           |
| Stress × Snacking          | −.16 (.19)             | −.85 (10715)           | [−.53, .21]   | .400           | .07 (.16)              | .43 (11508)            | [−.25, .38]   | .668           |

*Note.* Estimates of the main effects can be interpreted as predictors being person-mean centered. Positive and negative affect were multiplied by 10 in order to obtain more significant digits.

\*  $p < .05$ .

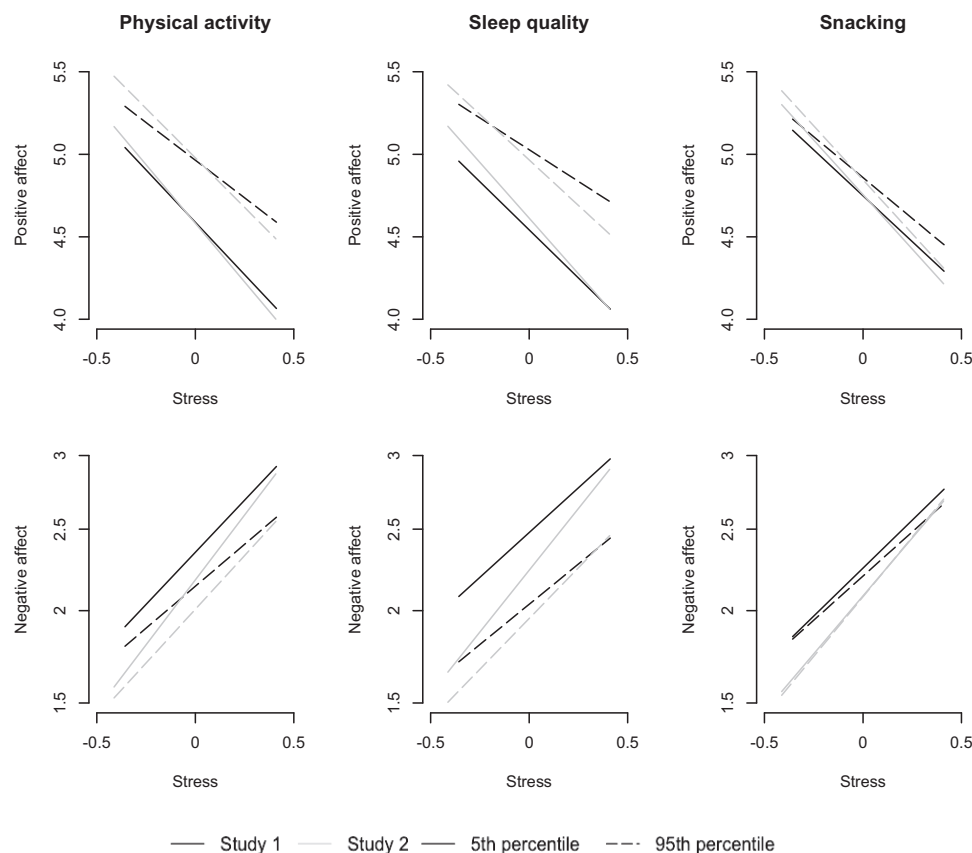


*Figure 1.* The interaction between daily health behaviors and daily stress as predictors of daily positive and negative affect in Studies 1 and 2. Values denote estimates from a multilevel model. Note that physical activity, sleep quality, and snacking (i.e., the moderators) were continuously distributed and were only regrouped in this figure into two categories, namely, high and low physical activity, sleep quality, and snacking (5th and 95th percentile, respectively), for illustrative purposes. We selected 5th and 95th percentiles because they represent contrasting values on either side of the respective health-behavior distribution without being too extreme. Stress, the predictor, was person-mean centered. Because negative affect was transformed to approximate normal distribution, axes of negative affect were back-transformed to simplify the interpretation.

In neither study did we find that amounts of daily snacking moderated the association between daily stress and affect. Thus, neither Hypothesis 2c<sub>1</sub> or 2c<sub>2</sub> was supported by our data.

Regions of significance (Preacher et al., 2006) are not reported because for all analyzed models, the slope coefficients were always significantly different from zero across the entire range over which each moderator was measured; only the effect size changed. Furthermore, all moderation analyses were conducted with respect to gender to examine whether the associations between stress and affect as a function of health behavior go in opposite directions for men versus women (and thus might, for instance, explain the null findings overall in snacking). In both studies, no three-way interaction between stress, physical activity, and gender on positive or negative affect was significant. Similar results were shown for sleep quality with one exception: In Study 1, the three-way interaction between stress, sleep quality, and gender on negative affect was significant ( $B = -0.94$ ,  $SE = 0.42$ ,  $p = .025$ ). This means that for men, the positive association between stress and negative affect was weaker the better sleep quality than usual they reported

on a given day, whereas for women, the positive association between stress and negative affect was not moderated by sleep quality. Furthermore, the three-way interactions between snacking, stress, and gender were not significant, again with one exception: In Study 2, the three-way interaction between snacking, stress, and gender predicting negative affect was marginally significant ( $B = -0.72$ ,  $SE = 0.37$ ,  $p = .049$ ). This means that for men, the positive association between stress and negative affect was weaker the more snacking than usual they reported on a given day, whereas for women, the positive association between stress and negative affect was stronger the more snacking than usual they reported on a given day.

Finally, we conducted additional analyses for participants with higher compliance rates. We reran all analyses including only participants with a compliance rate of at least 50% (Study 1: >30 assessments,  $n = 179$ , full sample  $N = 292$ ; Study 2: >32 assessments,  $n = 187$ , full sample  $N = 304$ ). These results were comparable to the results based on the full sample with regard to direction and size of coefficients.

## Discussion

The findings from the present intensive longitudinal studies suggest that different health behaviors may buffer the detrimental effects of stress on affect in young adults' daily lives. The more physically active than usual a person was on a given day or the better than usual a person's sleep quality had been during the previous night, the weaker the association between stress and affect; we found no such association for snacking. In other words, on more stressful days, physical activity and sleep quality, but not snacking, emerged as potential protective factors against deteriorating affect. These findings extend prior research in two important aspects: First, the present studies focused on naturally occurring variability in stress, health behaviors, and affect within the same person, whereas previous research mainly focused on between-person differences (e.g., [Ensel & Lin, 2004](#)) and therefore could only describe a snapshot of an individual's behavior. Second, above and beyond the previously explored stress-buffering role of physical activity (mostly in experimental or cross-sectional studies), the current article examined other health behaviors that are central to everyday life, namely, sleep quality and snacking.

On days on which participants reported more stress than usual, they also reported decreased positive affect and increased negative affect, respectively, which is in line with previous research ([Almeida, 2005](#); [N. Jacobs et al., 2007](#); [O'Hara et al., 2014](#)). The more physically active than usual a person was on a given day, the weaker the negative association between stress and positive affect as well as the weaker the positive association between stress and negative affect. Importantly, the interaction between physical activity and stress on positive affect was established in only one of the two studies. Methodological differences could be one potential explanation for the discrepant results between the two studies. Specifically, the distinct operationalizations of daily stress might have influenced participants' memory, that is, recognition (Study 2: "Select a category") versus recall (Study 1: "Report stressors in an open-question format"). Also, participants might have been more motivated to indicate stressors in Study 2, as selecting a category is often less work than describing a stressor in one's own words. Therefore, further research should clarify the role of physical activity as a buffer for the effects of stress on positive affect in everyday life. We would like to note that the present results support previous experimental (e.g., [Mata et al., 2013](#)) and cross-sectional (e.g., [Ensel & Lin, 2004](#)) studies. One potential mechanism of how physical activity may change the association between stress and affect could be a reduced cortisol response to stress: Daily stress and negative affect have been associated with a higher cortisol level and positive affect with a lower cortisol level ([Smyth et al., 1998](#)). Notably, acute physical activity has been associated with lower cortisol responses after stress ([Zschucke, Renneberg, Dimeo, Wustenberg, & Strohle, 2015](#)).

The better a person's sleep quality was during the previous night, the weaker the negative association between stress and positive affect, as well as the weaker the positive association between stress and negative affect. The association with negative affect was established in only one study. In keeping with the reasoning mentioned above, the distinct operationalization of daily stress might explain the difference between the two studies—that is, stress may have been underestimated in Study 1 and hence we could not detect the potential interaction. Furthermore in Study 1,

the association between stress and negative affect with respect to sleep quality was different for men and women. For men, a stress-buffering effect of sleep quality for negative affect was established, whereas for women, no such effect was observed. Because more women participated in the study (75% women), another explanation might be that analyses of the whole sample (including men and women) resulted in a nonsignificant effect. Therefore, further research is needed to clarify the role of gender for the relation between daily stress, sleep quality, and negative affect. A potential mechanism for the link between sleep, stress, and affect could be changes in amygdala activation ([Davis & Whalen, 2001](#)), which may be involved in the hypothalamic–pituitary–adrenal system ([Muscatell & Eisenberger, 2012](#)). Stress ([Roosendaal, McEwen, & Chattarji, 2009](#)) as well as sleep deprivation ([Kahn, Sheppes, & Sadeh, 2013](#)) have been associated with amygdala activation. For example, [Minkel and colleagues \(2014\)](#) showed that sleep-deprived individuals had an elevated cortisol response after stress, which might have been due to increased amygdala activation.

Contrary to our hypotheses about snacking, both studies showed that the association between daily stress and positive and negative affect did not differ as a function of snacking. These results do not support potential stress-buffering or detrimental effects of snacking on affect. One reason might be that the effect of snacking could be relatively weak and short-lived compared with physical activity and sleep quality. For example, [Macht and Dettmer \(2006\)](#) assessed affect 5, 30, 60, and 90 min after snacking and showed a positive association between snacking and positive affect. Another reason might be that the potential stress-buffering effect occurs in opposite directions for women and men, resulting in a nonsignificant overall effect. In Study 2, snacking showed a stress-buffering effect for men, whereas for women, the positive association between stress and negative affect was stronger with respect to snacking. However, this three-way interaction between stress, snacking, and gender was not replicated and not established for positive affect. Thus, future research could investigate gender differences in the association between snacking, stress, and affect with a more intense study design (e.g., several assessments per day) to capture any short-term associations.

## Limitations

Most data in the current studies were obtained using self-report. It is important to note that self-reported health behaviors correlated with behavioral measures of physical activity and sleep obtained by actigraph and actual snack intake in a laboratory setting. In addition, with the exception of two results (which showed a similar tendency), all findings were replicated across the two studies. The interaction effects were comparably small, as is common in diary studies; thus, the effects represent day-to-day fluctuations in perception and behaviors, which are naturally smaller than, for example, effects based on experimental interventions. Furthermore, due to the within-person design and person-mean centering, potential influences of confounding factors such as gender or social status and response tendency were eliminated. However, it might be that within-person associations are different for men and women. Thus, three-way interactions were analyzed and with the exception of two results, no differences between men and women across both studies were observed.

A further limitation was the observational study design, which does not allow drawing causal inferences or disentangling the chronological order in which behaviors may have influenced each other. Notably, the design of the current study was not informative for potential time-lag effects, such as whether increased physical activity on the previous day predicts the association between stress and affect on the next day, because potentially, such time lags would be too large to identify those effects. For example, Wichers and colleagues (2012) showed that the effect of physical activity on positive affect lasted up to about 3 hr. Our study design cannot capture effects lasting less than about 24 h. Therefore, it would be interesting for future researchers to examine shorter time intervals between assessments.

Third, the dropout rate was 10% in both studies and the compliance rate was 62% for Study 1 and 60% for Study 2. In relation to other studies using intensive longitudinal assessments with university students, this is a comparable dropout rate and a somewhat lower compliance rate than others (e.g., 78% in a 7-day diary study with 70 assessments in Brans, Koval, Verduyn, Lim, & Kuppens, 2013; 89% in Galambos et al., 2009; and 82% in Kuppens, Oravecz, & Tuerlinckx, 2010, in diary studies with 140 assessments over 14 days). We consider it important that our study was of a substantially longer duration (an entire academic year), which might be an explanation for the lower compliance rate compared with Galambos et al.'s 89% (2009), or with Kuppens et al.'s 82% (2010).

Finally, results cannot be generalized to other universities, ages, and samples experiencing different levels of stress—especially because, in the present sample, participants with compliance rates of 50% or higher experienced lower levels of stress during the study. However, stress-buffering effects of physical activity have also been established in populations that experience higher levels of stress, such as employees (Ensel & Lin, 2004; Klaperski et al., 2012) or patients with chronic diseases (Latimer, Martin Ginis, & Hicks, 2005). Therefore, future researchers should elaborate on whether daily physical activity and daily sleep quality might also be valuable resources for affect in nonstudent populations—especially in people with higher levels of stress.

## Conclusion

On days with higher stress than usual, engaging in physical activity or having had a good night's sleep may serve as a stress buffer for affect, which is an important indicator of mental well-being. The current findings extend previous between-person studies by elucidating the naturally occurring day-to-day dynamics of stress, health behaviors, and affect. Such within-person results can inform potential targets for health-promotion and stress-prevention programs, which could help reduce the negative impact of stress in young adults. For example, one relevant public health message could be that especially on more stressful days than usual, young adults may benefit from being more physically active or getting a good night's sleep, which in turn may be associated with long-term mental and physical health.

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