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Physical Activity and Negative Affective Reactivity in Daily Life

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Objective: The results from experimental studies indicate that physically active individuals remain calmer and report less anxiety after the induction of a standardized stressor. The current study extends this research to real life, and examines whether daily physical activity attenuates negative affect that occurs in response to naturally occurring daily stressors. ***Method:*** The current study used data from the second wave of the National Study of Daily Experiences, a sub-study of the second wave of the Midlife in the United States Study (MIDUS-II) of 2,022 individuals aged 33-84 questioned nightly for eight consecutive days about their general affect and affective responses to stressful events and their engagement in physical activity. ***Results:*** Results indicated that while negative affect is significantly elevated on days with stressful events compared to days free of events in all individuals, these effects are attenuated in those who remain physically active when compared to those who were underactive. This was also true for any day participants were physically active. Importantly, negative affect in response to any specific stressor was reduced the closer in time that the stressor occurred to the bout of exercise in underactive participants, while, in active participants, negative affect in response to any stressor remained low throughout the entire day that participants reported that they were active. ***Conclusion:*** Given the significant mental and physical health implications of elevated affective reactivity observed in previous studies, the current study sheds further light on the importance of remaining physically active in times of stress.

Keywords: physical activity, affective reactivity, daily stressors

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Regular physical activity is associated with improvements in a range of outcomes, including delayed cognitive decline (Sofi et al., 2011), reduced depressive symptomatology equal to pharmaceuticals (Hoffman et al., 2011), and reduced risk of early mortality (Arem et al., 2015). A growing body of research has sought to identify the extent to which physical activity boosts positive affect (PA) and/or reduces negative affect (NA). Although it is clear that physical activity has direct effects on reports of daily experiences of affect, especially PA (Hogan, Mata, & Carstensen, 2013; Reed & Buck, 2009; Wichers et al., 2012), little is known about the extent to which physical activity might buffer against affective reactivity (i.e., changes in affect in response to experiences) in *daily life*. The current study examined whether physical activity mitigates NA in response to daily stressful events.

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Literature Review

Physical Activity and Affect

Affect is the conscious experience of neurophysiological states, marked by its valence and arousal (Russell, 1980; Russell & Barrett, 1999). The effects of physical activity on PA have been consistently found within laboratory (Cox, Thomas, & Davis, 2001; Ekkekakis, Hall, & Petruzzello, 2005; Tate & Petruzzello, 1995), daily process field-based (Hogan et al., 2013; Mata et al., 2012; Wichers et al., 2012), and intervention (Reed & Buck, 2009) studies.

There is little evidence to support the effects of physical activity on the experiences of NA (Hogan et al., 2013; Mata et al., 2012;

Poole et al., 2011; Wichers et al., 2012). For example, using ecological momentary assessments with repeated assessments 10 times per day for 5 consecutive days, Wichers and colleagues (2012) examined the lagged relationships between physical activity and PA and NA in over 500 female twins. Their results indicated that PA increased immediately after a bout of activity and lasted as long as 3 hr for women without histories of depression, and for an 1.5 hr for women with histories of depression. On the other hand, a bout of activity on any particular day had no immediate or lagged effects on NA. Mata and colleagues (2012) reported similar findings using similar methodologies (eight daily assessments for 7 days) in men and women.

Physical Activity and Affective Reactivity

Initial work by DeLongis, Coyne, Dakof, Folkman, and Lazarus (1982) revealed that the occurrence of daily stressors, ranging from work overload to interpersonal conflicts, had a significant impact on physical health (e.g., somatic complaints like chest pain, headaches) stronger than the effects of major life stressors. Since then, there has been an accrual of evidence that daily stressors predict daily physical and psychological well-being (Almeida & Kessler, 1998; DeLongis, Folkman, & Lazarus, 1988) and biological mediators of disease outcomes, such as daily cortisol output (Stawski, Cichy, Piazza, & Almeida, 2013) and inflammation (Gouin, Glaser, Malarkey, Beversdorf, & Kiecolt-Glaser, 2012).

Although daily events matter, how one responds affectively to these experiences appears to be especially important to health. Two recent studies, using data from the National Study of Daily Experiences, demonstrated that greater increases in NA on days with stressful events compared with days without stressful events was related to a greater incidence of affective disorders (Charles, Piazza, Mogle, Sliwinski, & Almeida, 2013) and chronic health conditions (Piazza, Charles, Sliwinski, Mogle, & Almeida, 2013) a decade later. In these studies, NA reactivity, defined as the changes in NA on stressor days compared with stressor-free days, reflects the expected byproduct (i.e., affect) of the stress and coping process.

How physically active and inactive individuals affectively respond to naturally occurring or laboratory-induced stressors has been far less studied compared with the broader work on general affective states. Laboratory studies have shown that physically active individuals are less likely to experience increases in general NA and discrete negative emotions after the induction of a laboratory stressor compared with those who are physically inactive. Rimmele and colleagues (2007, 2009) demonstrated that both male athletes and sedentary untrained adult males increased in reported anxiety and decreased in calmness in response to a stressor induced in the laboratory. However, these effects were significantly less pronounced in the athletes. Mata, Hogan, Joormann, Waugh, and Gotlib's (2013) laboratory study indicated that when depressed individuals were provided an opportunity to exercise prior to a sad mood induction task, they subsequently displayed similar mitigated affective responses to nondepressed individuals, whereas those who were depressed but who did not exercise continued to display elevated NA with repeated inductions. To date, the extent to which physical activity mitigates NA reactivity to daily stressors in real life settings is unknown.

The Current Study

The current study conceptualized NA reactivity similar to naturalistic studies that differentiated between days with and days free of stressors (Charles et al., 2013) and to laboratory studies that examined affective responses related to specific stressors (Puterman et al., 2014). Building upon previous laboratory studies (Mata et al., 2013; Rimmele et al., 2007), the current study examined three main research questions. First, drawing from this extant body of research, it was hypothesized that NA reactivity would be mitigated in those who are regular exercisers when compared with those who are not. Second, it was hypothesized that NA reactivity would be alleviated to a greater extent on days that individuals report being physically active when compared with days without such activity. Finally, given the demonstrated relationship in time between physical activity and affect (Wichers et al., 2012), this study further tested whether mitigating effects of physical activity are a function of when the bout of exercise occurs in relation to the stressor. With this in mind, it was hypothesized that attenuation effects would be more pronounced when exercise occurs proximally to the experience of the stressor when compared with when the exercise bout occurs more distally in time. In sum, by completing this series of detailed analyses, the current study represented an opportunity to paint a naturalistic picture of physical activity as a means of activating stress resiliency, by comparing exercisers with nonexercisers and days with and without bouts of physical activity as they relate to general NA and stressor-specific NA reactivity.

Method

The second wave of the Midlife in the United States Study (MIDUS II; http://midus.wisc.edu/), a longitudinal study of health and aging in the United States, contains a national sample of 4,963 individuals (ages 32–84 years; 53% female). The original wave, MIDUS-I (n = 7,108), was surveyed between 1995 and 1996, and was reassessed between 2004 and 2006 (average follow-up interval = 9 years; range = 7.8–10.4). A random subsample of 3,600 MIDUS II participants was recruited to participate in the second wave of the National Study of Daily Experiences (NSDE II), a substudy that examined their daily stressful experiences, affective states, and health behaviors. A total of 2,022 individuals (78% response rate) completed NSDE II (ages 33–84 years; M = 56 years, SD = 12.20; 57% female). MIDUS and NSDE study procedures were reviewed and approved by the Behavioral Sciences and the Health Sciences institutional review boards at the University of Wisconsin-Madison and The Pennsylvania State University. For more information about these studies, visit (http://midus.wisc.edu/).

Procedures

Participants in the NSDE II completed telephone interviews about their daily experiences over the course of eight consecutive evenings. The first and last day's interviews lasted approximately 15 to 20 min, and the other six interviews lasted approximately 10 to 15 min. They were asked questions about their affective states, stressors they experienced, health behaviors, and physical symptoms over the previous 24-hr period. After three consecutive

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nonresponse days, the research team terminated participation in NSDE II. A total of 14,912 interview days were completed for NSDE II's 2,022 participants (average response = 7.4/8 days; Almeida, McGonagle, & King, 2009).

Measures

Daily stressors. Daily stressors were assessed through the Daily Inventory of Stressful Events (Almeida, Wethington, & Kessler, 2002). The inventory asked respondents whether they experienced a stressor across seven domains: arguments with others, avoided an argument, stressor at work/school, stressor at home, discrimination, network stressor (event happened to a family member or close friend), or any other stressor. If any stressor occurred, respondents were asked what time it occurred. Responses were coded as 1 if a stressor occurred in a specific domain, or 0 if not. Responses were also summed for number of stressors reported per day.

Active day. Participants were asked how much time they spent "since this time yesterday" engaging in activities "that would cause you to break a sweat." If affirmative, participants were then asked to report the time at which they began their physical activity and the amount of time they engaged in the activity. This brief daily physical activity measure was adapted from the 12-item NDSE II general measure of physical activity (Cotter & Lachman, 2010), which has been found to display good internal consistency and criterion validity. The U.S. Office of Disease Prevention and Health Promotion's "Physical Activity Guidelines for Americans" (Physical Activity Guidelines Advisory Committee, 2008) recommends engaging in moderate levels of physical activity in bouts of no less than 10 min on most days that add up to 150 min per week. Moderate intensity is defined, in part, as a level of intensity that causes one to break a sweat. Thus, in the current study, a given day was considered an active day (1 = yes, 0 = no) if the bout of activity reported on that day made them break a sweat and lasted a minimum of 10 min. Thirty-three of the days with reported activity included bouts less than 10 min and were coded 0.

Activity status. Bouts of activity that were reported as occurring for a minimum of 10 min were then summed across the 8 days of study participation to determine their physical activity status. The recommended 150 min per week (Physical Activity Guidelines Advisory Committee, 2008) equate to approximately 21.4 min per day, which would correspond to 171.4 min across the 8 days of study. Thus, participants who completed more than 172 min during their participation in the study were categorized as "active" and those who did not were categorized as "underactive."

General NA. General NA was assessed by having participants rate, on a scale from 0 (*not at all*) to 4 (*all the time*), how often they experienced each of the following 14 emotions during the previous 24 hr: "restless or fidgety," "nervous," "worthless," "so sad nothing could cheer me up," "that everything was an effort," "hopeless," "lonely," "afraid," "jittery," "irritable," "ashamed," "upset," "angry," and "frustrated." These items come from the Nonspecific Psychological Distress Scale (Kessler et al., 2002) and a modified version of the Positive and Negative Affect Schedule (Watson, Clark, & Tellegen, 1988). General NA was calculated by taking the sum across all items, with higher scores reflecting higher NA (possible range scores = 0–64; actual range from data = 0−35.50). Measures derived from this instrument were found to be internally consistent (α = .91; see Raudenbush, Rowan, & Kang, 1991, for calculation method for nested data).

Stressor-specific NA. Stressor-specific NA was assessed by having participants rate, on a scale from 0 (*not at all*) to 3 (*all the time*), the extent to which they felt each of the following four emotions in response to each of the stressors they experienced: "angry," "nervous or anxious," "sad," and "shameful" (Almeida, Stawski, & Cichy, 2011). Stressor-specific NA was calculated by taking the sum across four affective items and seven stressors, with higher scores reflecting higher NA (possible range scores = 0–84; actual range from data = 0–35). Measures derived from this instrument were found to be internally consistent (α = .85).

Covariates. Covariates included in all analyses were sex (male = −1; female = 1), age (centered around the sample, M = 56.24), education (less than high school = 0; only high school = 1; college or vocational degree = 2; postgraduate education in progress or completed = 3), racial identification (White = 0; Black = 1; other = 2), chronic health conditions over the previous year (sum score of 30 possible items ranging from respiratory, cardiovascular, arthritis, and other health conditions, centered around the sample M = 2.54), daily smoking status (smoking day = 1; nonsmoking day = −1), and daily alcohol use on each day of assessment (none = −1; moderate = 0 [one to two drinks for males, one for females]; heavy = 1 [three or more for males, two or more for females]—based on daily alcohol consumption categories determined by U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2015).

Statistical Approach

All analyses were completed with SPSS Version 23. Descriptive statistics were computed for all variables, followed by bivariate analyses to determine whether potential covariates (sociodemographic, smoking and alcohol status, and chronic health conditions) were related to the a priori predictors (active day, activity status) and criterion variables (general and stressor-specific NA).

To test the hypotheses that NA reactivity is a function of activity status or active day, several multilevel analyses, including all covariates, were completed with random intercepts and fixed slopes using MIXED syntax with full maximum likelihood estimation in SPSS. Multilevel models with full maximum likelihood estimation are robust to missing data (Raudenbush & Bryk, 2002; Snijders & Bosker, 2012). General NA was regressed on (a) stressor day (yes/no), (b) activity status (active/underactive), (c) activity day (yes/no), and the interactions between stressor day (yes/no) with activity status (active/underactive) and activity day (yes/no). Stressor-specific NA was regressed on either activity status or activity day. MIXED syntax estimates the outcome (Y) as a function of one predictor variable (X), a moderator variable (Z) and their interaction (X*Z), producing four relevant coefficients: (1) β_0, (2) βx, (3) βz, and (4) βx^*z. Interpretation of the coefficients is similar to interpreting regression coefficients with two independent dichotomous variables coded 0 and 1 and including their interaction (see Cohen, Cohen, West, & Aiken, 2003, Chapter 9, for a detailed explanation). Briefly, using general NA as the outcome and stressor day and activity status as the two predictors, β_0 is the estimated mean NA when stressor day (Variable 1) and activity status (Variable 2) are both 0 (i.e., days without stressors in underactive participants). βx is the estimated *change* in NA

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from its estimated mean on days without stressors, coded 0, to days with stressors, coded 1, but only in underactive participants (coded 0). Adding the βx to β_0 thus provides the estimated mean NA on days with stressors in underactive participants. A significant interaction $\beta x^{*}z$ suggests that the change in estimated mean NA on stressor days compared with days free of stressors is different for underactive compared with active participants. To compute the estimated mean NA on days with and without stressors in active participants, activity status is reverse-coded and a MIXED model rerun. In this new model, β_0 and βx are the estimated mean NA on stressor-free days and the change to stressor days in active participants. Again, βx can be added to β_0 to compute an estimated mean NA on days with stressors in the active participants.

A three-level model was used to test the hypothesis that the mitigating effects of physical activity on NA reactivity is a function of *when* the bout of exercise occurs in relation to the stressor. Because multiple stressors could occur on each day for each person, the first level of the model (reflecting within-day variation) included each individual stressor-specific NA and the time it occurred subtracted from the time the bout of exercise started, allowing to account for the nonindependence in the data within persons and within days. The second level of the model included the variables that varied across days within individuals: that particular day's length of bout of exercise, number of stressors, and daily smoking and drinking status. Finally, the third level included the variables that only varied between participants: age, sex, race, education, and chronic conditions. To test the third hypothesis, a multilevel growth curve model determined the trajectory of stressor-specific NA as a function of the time difference between the bout of exercise and the occurrence of each individual stressor. Growth curve modeling with time treated as linear (time) and curvilinear (time^2) variables estimates an intercept, β_0, an initial rate of change, β_{time}, and curvature, β_{time^2}, and any significant time effects suggest that stressor-specific NA is a linear or curvilinear function of the time difference between the bout of exercise and occurrence of the stressor.

When appropriate, pseudo R^2 (Hedeker & Gibbons, 2006) was calculated to determine the proportional reduction in the unexplained variance between a more basic model that does not include any variables and ones that includes covariates and predictors. A pseudo R^2 is determined by subtracting the estimate of covariate parameter for the residual or intercept (depending on level of analysis) for the more advanced model including the new variables from the more basic model and then dividing this value from the more basic model's estimate.

Results

Few participants were missing sociodemographic data (0.2% were missing race or education data). Eighty-seven percent of participants completed 7 or all of the 8 days of the study, and a very small minority (2.9%) of participants missed five or more phone calls. A greater number of missing days was related to younger age ($r = -.12$, $p < .001$) and lower education (ANOVA, $F[3, 2014] = 5.72$, $p = .001$). Post hoc analyses demonstrated that those without a high school diploma completed fewer assessments than those at the three other education levels (*M*s range = 0.46 to 0.51). Race was also related to greater number of days not completed (ANOVA, $F[2, 2013] = 33.17$, $p < .001$), and post hoc analyses demonstrated that Black participants completed fewer assessments than other participants (*M*s range = 0.51 to 0.72).

Descriptive statistics for all variables are presented in Table 1. Participants were, on average, aged 56 and were predominantly White (84.5%). Nearly half (48.2%) of the participants had high school or equivalent education, and another 45.5% had completed college. The majority (89.2%) of participants reported zero or moderate amounts of alcohol (no more than 8 for women or 16 for men) during the 8 days of the study. A majority of participants were nonsmokers (84.8%). Participants also reported, on average, 2.54 chronic health conditions over the previous year.

Bivariate analyses (*t* tests, Pearson correlations, ANOVAs) revealed that the number of days participants reported being physically active was related to being older ($r = .07$, $p = .001$), male, $t(2016) = 2.14$, $p = .03$, having fewer chronic health conditions ($r = -0.08$, $p < .001$), and not smoking, $t(2016) = 2.81$, $p = .005$. Race ($p = .24$), education ($p = .08$), and alcohol status ($p = .15$) were unrelated to number of days being physically active. Similar significant associations between covariates and activity status (active vs. underactive) were apparent, whereby active participants were older, $t(2020) = -2.05$, $p = .04$, male, $\chi^2(2) = 26.62$, $p < .001$, and had fewer health conditions, $t(1953) = 2.82$, $p = .005$. Two hundred eight (10.3%) participants reported no days with any stressors and were excluded from the analyses because the occur-

Table 1
Descriptive Statistics for Sociodemographics, Health Behaviors, Health Conditions, and General and Stressor-Specific Reactivity for All Participants Included in the National Study of Daily Experiences II

Characteristic	Statistic
Age, *X* (*SD*)	56.24 (12.2)
Sex	
Female, *n* (%)	1,157 (57.2)
Male, *n* (%)	865 (42.8)
Race	
White, *n* (%)	1,703 (84.5)
Black, *n* (%)	228 (11.3)
Other, *n* (%)	85 (4.2)
Education	
<High school, *n* (%)	123 (6.3)
High school or equivalent, *n* (%)	973 (48.2)
College completed, *n* (%)	538 (26.7)
Postgraduate, *n* (%)	379 (18.8)
Chronic health conditions, *X* (*SD*)	2.54 (2.48)
Drinking status	
None, *n* (%)	1,055 (52.2)
Moderate, *n* (%)	784 (38.8)
Heavy, *n* (%)	183 (9.1)
Smoking status *n* (%)	
No, *n* (%)	1,711 (84.8)
Yes, *n* (%)	307 (15.2)
Active days, number, *X* (*SD*)	3.35 (2.51)
Activity status	
Active, *n* (%)	1,077 (53.3)
Underactive, *n* (%)	945 (46.7)
General negative affect, *X* (*SD*)	2.92 (3.89)
Stressor-specific negative affect, *X* (*SD*)	4.03 (2.88)

Note. All data for general and stressor-specific negative affect were first averaged per participant, and then a general average for the full sample was taken.

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rence of stressors is integral to the concept of affective reactivity. Of those who reported any days with stressors (n = 1,814), 56% (n = 1,062) of participants were classified as physically active. Physical activity was not associated with exposure to daily stressors. Of those who reported any days with stressors, active and underactive participants had similar number of days with the occurrence of stressors: 3.21 days compared with 3.16 days, respectively, $t(1812) = 0.58$, $p = .56$. Active and nonactive days had similar likelihood of having a stressful event occur (39.5% vs. 38.3%), $\chi^2(1) = 2.24$, $p = .13$. Number of stressful events reported also did not differ on active days versus inactive days across all participants, $t(14889) = -0.37$, $p = .71$.

General and stressor-specific NA were regressed on the covariates in two separate multilevel models. In each model, Whites were the referent group, as was postgraduate education. Younger adults ($\beta = -0.62$, standard error [SE] = 0.01, 95% confidence interval [CI] [−0.08, −0.05], $p < .001$) and those with more chronic health conditions ($\beta = 0.47$, $SE = 0.03$, 95% CI [0.41, 0.53], $p < .001$) reported greater estimated general NA. Additionally, Black participants ($\beta = 0.63$, $SE = 0.25$, 95% CI [0.15, 1.12], $p = 0.011$) had greater estimated general NA than White participants, whereas participants in other racial groups ($p = .65$) did not differ from White participants. Participants with a college degree but who did not pursue postgraduate education ($\beta = -0.57$, SE = 0.23, 95% CI [−1.02, −0.13], $p = .012$) and participants who completed only high school or GEDs ($\beta = -0.44$, $SE = 0.21$, 95% CI [−0.85, −0.03], $p = .034$) had lower estimated general NA than those who pursued postgraduate education. Those with less than a high school diploma had similar levels as those who pursued postgraduate education ($p = .92$). Estimated general NA on days that participants drank heavily ($p = .07$) or moderately ($p = .59$) was similar to days with no alcohol. Days participants reported smoking was related to greater estimated general NA than days when smoking was not reported ($\beta = 0.40$, $SE = 0.10$, 95% CI [0.22, 0.58], $p < .001$). Significant estimates were similar with regard to stressor-specific NA, though women also had significantly greater estimates of stressor-specific NA compared with men ($\beta = 0.35$, $SE = 0.07$, 95% CI [0.21, 0.49], $p < .001$), and on moderate drinking days, participants' estimates for stressor-specific NA was higher than on days with no drinks ($\beta = 0.63$, $SE = 0.16$, 95% CI [0.32, 0.94], $p < .001$). Including all the covariates accounted for 18% and 20% (pseudo $R^2 = 0.18$ and 0.20) of the previously unexplained variation in general and stressor-specific NA, respectively.

In independent models including all covariates, general NA was regressed on (a) stressor day (no = 0, yes = 1; $\beta_{stressorday}$), (b) activity status (no = 0, yes = 1; $\beta_{activitystatus}$), and (c) physically active day (no = 0, yes = 1; $\beta_{activeday}$). Average general NA on stressor days was significantly higher ($\bar{X} = \beta_0 + \beta_{stressorday}$ = 4.68) than general NA on stressor-free days ($\bar{X} = 2.26$; $\beta_0 = 2.26$, $SE = 0.19$, 95% CI [1.89, 2.62], $p < .001$; $\beta_{stressorday} = 2.43$, $SE = 0.06$, 95% CI [2.31, 2.55], $p < .001$). Active participants reported lower general NA across all days ($\bar{X} = 3.24$) than underactive participants ($\bar{X} = 3.76$; $\beta_0 = 3.76$, $SE = 0.22$, 95% CI [3.34, 4.19], $p < .001$; $\beta_{activitystatus} = -0.52$, $SE = 0.15$, 95% CI [−0.82, −0.22], $p = .001$). Days with a bout of exercise had significantly lower general NA ($\bar{X} = 3.37$) than days without a bout of exercise ($\bar{X} = 3.58$; $\beta_0 = 3.58$, $SE = 0.20$, 95% CI [3.18, 3.97], $p < .001$; $\beta_{activeday} = -0.21$, $SE = 0.07$, 95% CI [−0.34, −0.08], $p = .002$). Pseudo R^2s demonstrated an additional 10%, 1%, and 1% reduction in unexplained variance in general NA models including stressor day, activity status, and activity day, respectively.

> *Hypothesis 1:* Individuals who reach levels of physical activity comparable with those recommended by the Centers for Disease Control and Prevention have attenuated affective reactivity compared with those who do not.

General NA was regressed on two dichotomous variable—stressor day and activity status—their interaction, and all covariates. Results indicated a significant interaction, $\beta_{interaction}$ = −0.38, $SE = 0.12$, 95% CI [−0.62, −0.15], $p = .001$. As seen in Figure 1, general NA was significantly lower on stressor-free days ($\beta_0 = 2.10$, $SE = 0.20$, 95% CI [1.70, 2.49], $p < .001$) and affective reactivity was significantly attenuated ($\beta_{stressorday}$ = 2.26, $SE = 0.08$, 95% CI [2.10, 2.41], $p < .001$) in physically active participants compared with those who were underactive ($\beta_0 = 2.44$, $SE = 0.21$, 95% CI [2.03, 2.85], $p < .001$; $\beta_{stressorday} = 2.64$, $SE = 0.09$, 95% CI [2.47, 2.81], $p < .001$). The difference in estimated general NA on days with stressors compared with days without stressors corresponded to a 14.4% reduction (100 – [(active $\beta_{stressorday}$/underactive $\beta_{stressorday}$)*100]) in affective reactivity between active and underactive participants.

Next, stressor-specific NA across the seven domains of daily stressors was regressed on activity status, all covariates, and, additionally, number of stressors reported that day. Results indicated that active participants had similar levels of stressor-specific NA across the seven domains to the underactive participants ($\beta_0 = -0.29$, $SE = 0.19$, 95% CI [−0.66, −0.08], $p = .12$; $\beta_{activitystatus} = 0.02$, $SE = 0.12$, 95% CI [−0.21, 0.25], $p = .86$).

> *Hypothesis 2:* Affective reactivity is mitigated on active compared with inactive days.

General NA was regressed on two variables—stressor day and exercise day—their interaction, covarying age, sex, race, education, chronic health conditions, daily smoking, daily alcohol, and activity status (recoded −1 and 1 so that estimated NA corresponds to the average person in the study). Results indicated a significant interaction ($\beta_{interaction} = -0.45$, $SE = 0.11$, 95% CI

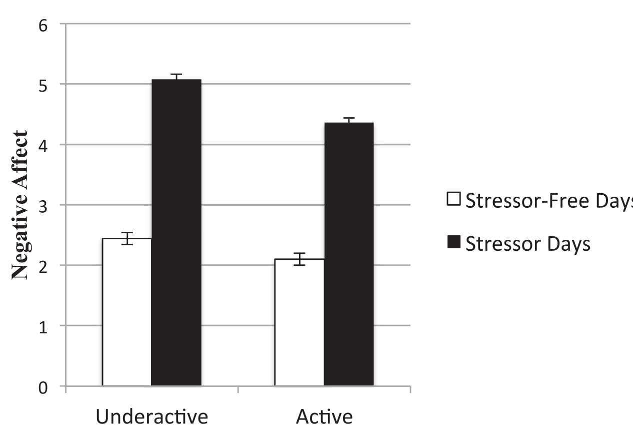

Figure 1. Estimated general negative affect on days with and without stressors in active and underactive participants (±standard error).

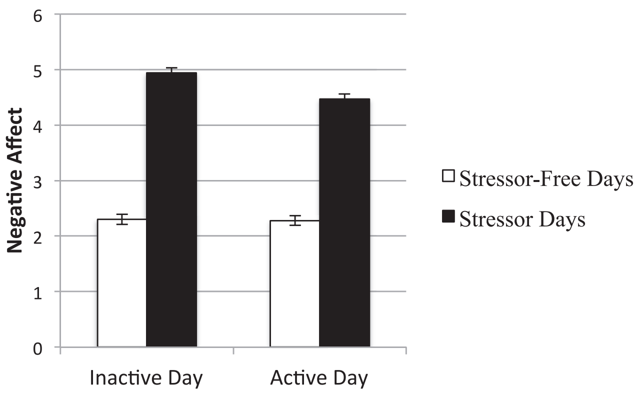

Figure 2. Estimated negative affect on days with and without stressors on days participants were active compared with days they were not (±standard error).

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[−0.67, −0.23], $p < .001$). As seen in Figure 2, affective reactivity was significantly attenuated (i.e., 17.0% reduction) on active ($\beta_0 = 2.28$, $SE = 0.19$, 95% CI [1.90, 2.66], $p < .001$; $\beta_{stressorday} = 2.19$, $SE = 0.08$, 95% CI [2.02, 2.35], $p < .001$) compared with inactive ($\beta_0 = 2.30$, $SE = 0.19$, 95% CI [1.92, 2.68], $p < .001$; $\beta_{stressorday} = 2.64$, $SE = 0.08$, 95% CI [2.48, 2.79], $p < .001$) days.

Next, stressor-specific NA across the seven domains of stressors was regressed on whether the day was an active day or not, including all covariates, activity status, and the number of reported stressors. Results indicated that active and inactive days had similar levels of stressor-specific NA across the six domains ($\beta_0 = -0.25$, $SE = 0.18$, 95% CI [−0.61, 0.10], $p = .17$; $\beta_{activeday} = -0.06$, $SE = 0.09$, 95% CI [−0.24, 0.12], $p = .51$).

> *Hypothesis 3:* Stressor-specific negative affect is attenuated the more proximal the occurrence of the stressor is to the report of an activity bout.

A three-level multilevel growth curve model examined whether NA in response to any stressor was a function of the amount of time between the bout of exercise and the occurrence of the stressor, including all covariates, number of stressors reported during the day, and activity status. Linear and curvilinear effects were not significant (*p*s > .50). Results did reveal a significant interaction with activity status for the curvilinear effects only ($\beta_{interaction} = -0.01$, $SE = 0.003$, 95% CI [−0.01, −0.001], $p = .043$) suggesting that active and underactive participants significantly differed in how the timing of a bout of activity, relative to the occurrence of a stressor, impacted NA in response to the stressor. Follow-up analyses within active participants suggested stable stressor-specific NA with no significant changes throughout the day ($\beta_0 = 2.66$, $SE = 0.24$, 95% CI [2.20, 3.12], $p < .001$; $\beta_{time} = -0.004$, $SE = 0.02$, 95% CI [−0.03, 0.19], $p = .70$; $\beta_{time^2} = -0.002$, $SE = 0.002$, 95% CI [−0.005, 0.001], $p = .27$). For underactive participants, though, stressor-specific NA varied as a function of the timing between the stressor and the bout of activity, evidenced by a significant curvilinear time effect ($\beta_0 = 2.11$, $SE = 0.48$, 95% CI [1.17, 3.05], $p < .001$; $\beta_{time} = -0.01$, $SE = 0.02$, 95% CI [−0.05, 0.04], $p = .77$; $\beta_{time^2} = 0.01$, $SE = 0.003$, 95% CI [0.001, 0.013], $p = .023$). Figure 3 illustrates these effects.

Discussion

In the current study, physical activity was not related to exposures to stressors but was related to NA reactivity. Although all participants significantly increased their experience of NA on stressor days compared with stressor-free days, individuals who were physically active did not increase to the same extent as less physically active individuals. Results indicated a 14% reduction in general NA on stressor days compared with days free of stressors between participants who were active compared with those who were underactive. General NA reactivity was also reduced (17%) on days in which participants reported a bout of exercise compared with days without exercise, independent of their general activity status. On days with stressors, reported specific NA in response to stressors did not differ by general activity status or activity day status. However, the current study did find evidence that on active days, specific NA experienced in response to each individual stressor was a function of the time a bout of activity occurred from the time a stressor occurred, but only for those who were underactive. This was not the case for those who reached a level of activity comparable with Centers for Disease Control and Prevention recommendations (Physical Activity Guidelines Advisory Committee, 2008) during the course of the study, as these individuals reported stable stressor-specific NA regardless of the time between the activity bout and the occurrence of the stressor.

Few studies have examined the effects of physical activity on psychological or physiological parameters in daily life. A recent 3-month exercise-based intervention study in inactive adults demonstrated that students randomized to an exercise group displayed elevated daily and nightly heart rate variability (HRV) during final exam week compared with those in the control group (von Haaren et al., 2016). HRV is a measure of the balance in autonomic control between the parasympathetic and sympathetic nervous systems, and elevated values infer a calmer or less activated physiologic arousal state. The current study is the first to extend the advantages of physical activity, albeit observationally, to affective responses to real-life daily stressors. It is unclear, though, whether providing physically inactive adults with an opportunity to become physically active through intervention ameliorates daily NA reactivity.

Unclear, as well, is whether individuals who are physically active simply do not react to the same extent to stressors as those less active or whether they react similarly but recover faster. Laboratory research indicates that in response to an acute laboratory stressor, active individuals remain calmer compared with those less active. The current study indicates that NA reported in response to any specific stressor in physically active individuals is stable, independent of the time between the stressor and the activity bout whereas less active individuals experience dampened NA closer in time between the two events. It seems, then, that the buffering potential of a bout of exercise on the experience of NA on stressor days and in response to specific stressors becomes embedded in those who are active on a regular basis. This study does not reveal whether a bout of exercise suppresses or reconfigures the end-of-day recall of the intensity of the affective experience of a stressor that occurred hours earlier or mitigates the actual experience of a stressor in real-time. Laboratory stressor and

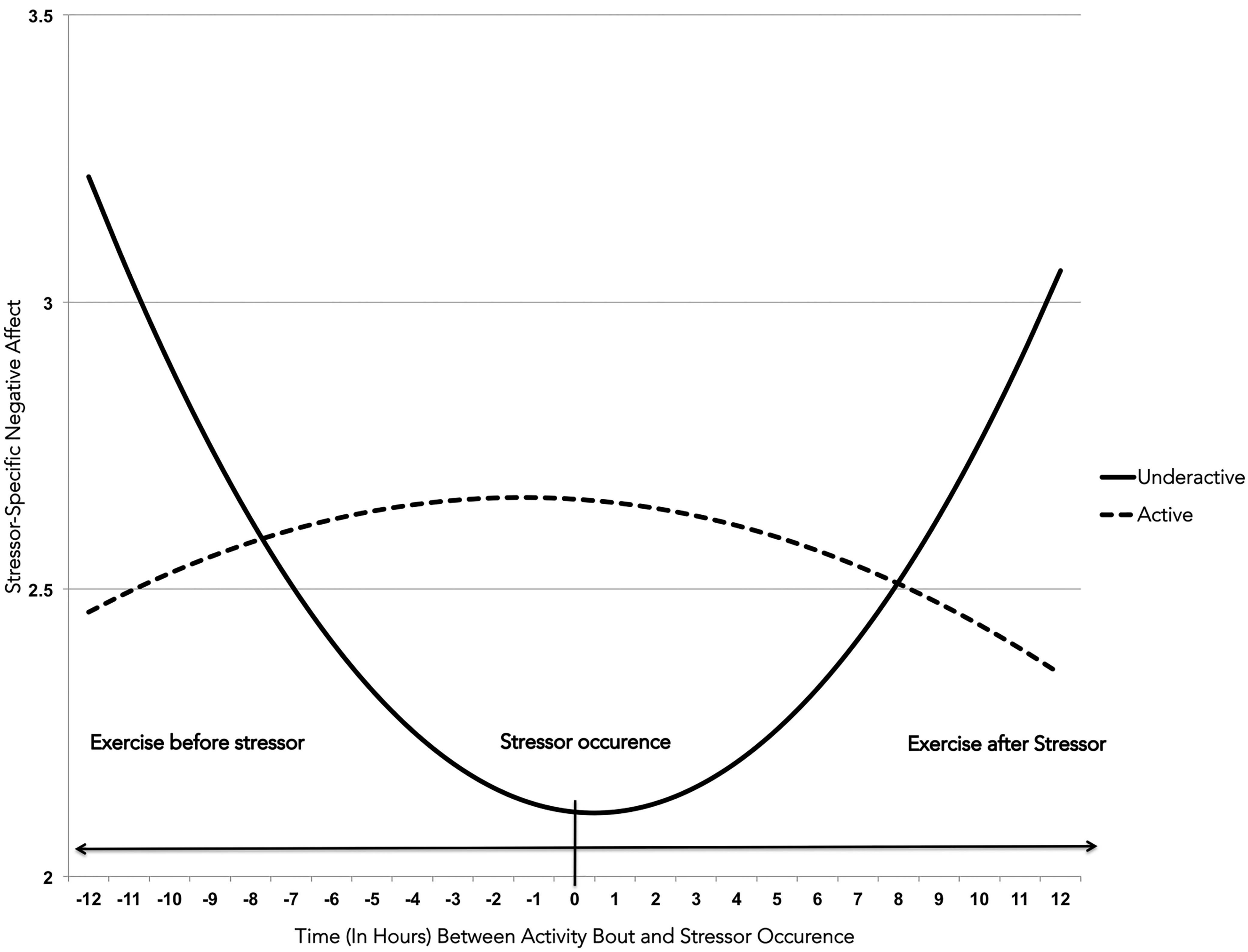

Figure 3. Stressor-related negative affect as a function of time between the occurrence of the stressor and when physical activity occurred among active and underactive participants.

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exercise manipulations are required to disentangle these possibilities.

The current study has several strengths. The study was well powered, which allowed capturing the occurrence of a wide array of real life stressors among individuals who were both active and underactive. The use of phone calls to survey the participants also allowed the team of research assistants to clarify any participants' questions that may otherwise have remained unanswered in self-reported online or paper surveys. The current study was further able to control for several important sociodemographic and behavioral factors associated with stressor exposure or physical activity, including age, sex, race, education, health conditions, and even smoking and alcohol use. Future research should attempt to capture dietary practices on a daily basis, based on findings that eating highly palatable foods improves both psychological and physiological stress responses (Macht & Mueller, 2007; Tomiyama, Dallman, & Epel, 2011).

The current study, however, does have limitations. End-of-day recall represents a significantly improved assessment technique over retrospective reports to understand the unfolding of stress on a daily basis and affect (DeLongis, Hemphill, & Lehman, 1992), though ecological momentary assessments may be more appropriate than end-of-day recall to adequately assess the relationship between a bout of activity and NA in response to a stressful event, as done in the final analysis. Furthermore, the emotional and time burden on participants when assessing daily mood and stressors requires brevity in the questions—usually a one-item face valid question amenable to repeated assessment (Iida, Shrout, Laurenceau, & Bolger, 2012).

Another limitation is that physical activity was assessed with a self-report measure. Most self-report instruments, such as the International Physical Activity Questionnaire (Booth, 2000), provide a retrospective assessment of physical activity accrued over a prolonged period of time, typically 1 week. In light of concerns with memory decay associated with such weekly retrospective measures, daily assessments of life experiences (Almeida et al., 2002; Kahneman, Krueger, Schkade, Schwarz, & Stone, 2004) have received increased usage within the behavioral sciences. Additionally, although the brief measure of physical activity embedded within the NSDE II interview protocol aligns well with current physical activity guidelines (Physical Activity Guidelines Advisory Committee, 2008), and displays sound content validity (vis a vis content relevance and representativeness; Messick, 1995), it should be noted that this brief measure has not been formally tested for convergent validity (e.g., in relation to objective measures such as accelerometry). In the current study, participants were asked whether they engaged in activities that made them break a sweat, one important factor in determining intensity, but not the only one. Intensity (light, moderate, or vigorous) is also defined by shortness of breath, fatigue, and capacity to carry on a conversation. Results indicate that 56% of the sample was active during the 8 days of data collection using the definition that only included sweating and with reference to the recommended guidelines of 150 min of moderate to vigorous activity per week, with each bout lasting at least 10 min, similar to the U.S. national average reported in 2011 (Centers for Disease Control and Prevention, 2015). Studies using accelerometers for objective activity measurement indicate a significantly reduced percent of the population active at levels recommended by the CDC (Tucker, Welk, & Beyler, 2011). Future studies should capture activity during the day with multimethod approaches including accelerometry data for real-time activity and repeated daily self-reported assessments for activities not captured adequately by these devices (i.e., swimming and biking), and that define moderate intensity with the full range of defining components. Such an enterprise would enable researchers to better understand, with greater sensitivity, the relationship between physical activity, the occurrence of stressful events and NA as they unfold throughout the day.

Physical activity has a wide range of beneficial effects on mental and physical health. The current study demonstrated that negative affective reactivity, previously demonstrated to be significantly associated with long-term mental and physical health problems, is less pronounced if individuals are physically active. Although physical activity may not reduce the likelihood of the occurrence of stressful events, it may bolster people's capacity to psychologically manage the stressor in a more effective way. The current study's findings are observational in nature, however, and intervention studies investigating *changes* in affective reactivity in previously inactive individuals who are provided the opportunity to become active are strongly needed.

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