



Bugl, P., Schmid, J., Stadler, G., Reuter, M., & Gawrilow, C. (2017). Zooming into daily life: Within-person associations between physical activity and affect in young adults. *Psychology & Health*.

**Zooming into Daily Life: Within-Person Associations
Between Physical Activity and Affect in Young Adults**

Journal:	<i>European Health Psychology Society</i>
Manuscript ID	GPSH-2016-0320.R3
Manuscript Type:	Psychology and Health
Keywords:	accelerometry, affect, physical activity, intensive longitudinal design, within-person association

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4 **Zooming into Daily Life: Within-Person Associations Between Physical**
5 **Activity and Affect in Young Adults**
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9 Objective: Negative affect in daily life is linked to poorer mental and physical
10 health. Activity could serve as an effective, low-cost intervention to improve
11 affect. However, few prior studies have assessed physical activity and affect in
12 everyday life, limiting the ecological validity of prior findings. This study
13 investigates whether daily activity is associated with negative and positive
14 evening affect in young adults.
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17 Design: Young adults ($N = 189$, $Mdn = 23.00$) participated in an intensive
18 longitudinal study over 10 consecutive days.
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21 Main Outcome Measures: Participants wore accelerometers to objectively assess
22 moderate-to-vigorous physical activity continuously throughout the day and
23 reported their affect in time-stamped online evening diaries before going to sleep.
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25 Results: On days when participants engaged in more activity than usual, they
26 reported not only less depressed and angry evening affect but also more vigor and
27 serenity in the evening.
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30 Conclusion: Young adults showed both less negative and more positive affect on
31 days with more activity. Physical activity is a promising health promotion
32 strategy for physical and mental well-being.
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36 Keywords: accelerometry; affect; physical activity; intensive longitudinal design;
37 within-person association
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40 Running head: Physical activity and affect within persons
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Introduction

How we feel is crucial for mental and physical health. Transient and subjective episodes of feelings that can be easily changed by context constitute affect (Cranford et al., 2006). Negative affect (e.g., depressed, angry, and anxious affect) in everyday life is associated with poorer mental and physical health (Charles, Piazza, Mogle, Sliwinski, & Almeida, 2013; Kiecolt-Glaser, McGuire, Robles, & Glaser, 2002). Positive affect (e.g., vigor, serenity) in everyday life is associated with, for instance, longevity (Diener & Chan, 2011).

Short-term fluctuations in negative and positive affect from day to day or within days are a common phenomenon (Eid & Diener, 1999). In addition, during early adulthood (between 20 and 30 years of age), negative affect is reported more frequently (Stone, Schwartz, Broderick, & Deaton, 2010) and positive affect is lower than in later adulthood (Carstensen et al., 2011). Because of the association between affect in everyday life and health, this age group is the focus of the present study. Identifying processes that may help young adults improve their everyday affective experiences is important for both individuals (e.g., to improve health and well-being) and for society (e.g., to reduce health care costs) and may have benefits for health promotion.

Prior studies on the association between physical activity and affect

Physical activity is “any bodily movement [...] that requires energy expenditure” (World Health Organization [WHO], 2010, p.53) and a low-cost and easily accessible intervention with multiple beneficial effects. National and international health boards recommend engaging in at least 30 minutes of moderate activity 5 days per week for primary prevention of chronic disease (American Health Association, 2014; European Working Group, 2008). Meta-analyses demonstrate that physical activity interventions

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3 reduce negative affect with small to moderate effect sizes in clinical and non-clinical
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5 adult samples (e.g., depressed samples: Lawlor & Hopker, 2001; Rimer et al., 2012;
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7 healthy samples: Conn, 2010). Importantly, the intensity and frequency of physical
8
9 activity seem to moderate the effect on affect (Dunn, Trivedi, & O'Neal, 2001).
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11 Engaging regularly in *moderate-to-vigorous* physical activity has been linked to
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13 reduced negative affect in cross-sectional studies (e.g., Poole et al., 2011), longitudinal
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15 studies (e.g., Mammen & Faulkner, 2013) and intervention studies (e.g., Parfitt, Rose, &
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17 Markland, 2000). So far, however, the association between physical activity and
18
19 positive affect has been studied less frequently. Two meta-analyses suggest that
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21 physical activity interventions of low to moderate intensity increase positive affect
22
23 (Puetz, O'Connor, & Dishman, 2006; Reed & Buck, 2009). Additionally, studies
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25 addressing fatigue, which we refer to as a slight negative feeling of lacking energy, are
26
27 rather rare. One meta-analysis indicates that regular physical activity is associated with
28
29 less fatigue (Puetz et al., 2006). Potential mechanisms that are discussed as drivers of
30
31 the positive influence of physical activity on affect are physiological processes (e.g.,
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33 increased neuroplasticity; Eyre & Baune, 2012) and psychological processes (e.g.,
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35 increased self-efficacy; Ryan, 2008; for an overview, see Lehnert, Sudeck, &
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37 Conzelmann, 2012), with the joint effects of these processes still in dispute.
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43 In sum, previous research has supported the notion of benefits of physical
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45 activity interventions in decreasing negative affect and provided initial evidence in
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47 terms of increasing positive affect. To derive implications for health promotion and
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49 enrich current activity recommendations, it is important to analyze the interrelations
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51 between activity and affect in young adults' everyday lives.
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55 ***The challenge of studying activity and affect within persons in everyday life***

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58 The studies reviewed so far are based on comparisons between persons (i.e., cross-
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3 sectional studies, e.g., Poole et al., 2011) and activity intervention studies (e.g., Conn,
4
5 2010). The generalizability of these prior results on the activity-affect association in
6
7 everyday life may be limited for the following reasons. First, physical activity was often
8
9 assessed using self-reports of past activity, which overestimate the actual amount of
10
11 activity compared to objective measures of activity (e.g., accelerometers; Prince et al.,
12
13 2008) and may be prone to recall bias. Second, experimentally manipulated, directed
14
15 and supervised physical activity, as is commonly applied in interventions studies (e.g.,
16
17 Conn, 2010), is likely quite different from naturally occurring self-initiated activity in
18
19 everyday life. In everyday life, people engage in structured activities (e.g., going to the
20
21 gym) as well as unstructured spontaneous activities (e.g., commuting, household
22
23 chores) that add up to a total daily amount of activity. Whether naturally occurring self-
24
25 initiated activity is linked to affect has rarely been studied (for an exception, see
26
27 Kanning, Ebner-Priemer, & Schlicht, 2013). Moreover, the generalizability of prior
28
29 results on the activity-affect association at the within-person level may also be limited:
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31 Cross-sectional results on the activity-affect association are based on comparisons
32
33 between persons, showing, for instance, that persons who habitually engage more often
34
35 in physical activity report more positive affect than less active persons (e.g., Pasco et
36
37 al., 2011). These results, however, cannot be directly transferred to the within-person
38
39 level because associations at the between-person and within-person level may differ and
40
41 may even go in opposite directions-(Hamaker, 2012; Molenaar & Campbell, 2009).
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43 Thus, between-person results are not a valid source of information for inferring how
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45 physical activity and affect actually covary within persons across time in everyday life.
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53 ***Importance of studying within-person associations between activity and affect***
54
55 ***in everyday life***
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57 The challenge of studying fluctuating experiences and behaviors within persons across
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3 time can optimally be met by *intensive longitudinal designs* where the same individuals
4
5 are repeatedly assessed in their everyday lives (Bolger & Laurenceau, 2013). Intensive
6
7 longitudinal designs are able to capture “life as it is lived“ (Bolger, Davis, & Rafaeli,
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9 2003, p. 580) and can further contribute to: (a) a more precise view of day-to-day
10
11 changes in individuals’ physical-activity and affect, as well as their association, due to
12
13 assessments that approximate *real time*; (b) a description of naturally occurring physical
14
15 activity and affect and thus more ecologically valid data that increases the
16
17 generalizability of study results due to the fact that assessments were made in *real life*;
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19 and (c) conclusions about within-person processes due to repeated assessments *within*
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21 *individuals* (Fahrenberg, Myrtek, Pawlik, & Perrez, 2007; Reis, 2012).
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25 So far, only a few studies have addressed the within-person association between
26
27 physical activity and negative affect in everyday life revealing mixed findings (for a
28
29 review, see Liao, Shonkoff, & Dunton, 2015). In adolescents, two studies found within-
30
31 person associations between objectively assessed activity and reduced negative same-
32
33 evening affect (Gawrilow, Stadler, Langguth, Naumann, & Boeck, 2016) and reduced
34
35 negative next-morning affect for female participants (Langguth, Schmid, Gawrilow, &
36
37 Stadler, 2016). Some studies have shown no association between activity and negative
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39 affect on the within-person level in healthy adult samples (Giacobbi, Hausenblas, &
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41 Frye, 2005; Hyde, Conroy, Pincus, & Ram, 2011; Kanning, Ebner-Priemer, & Schlicht,
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43 2015; Schwerdtfeger, Eberhardt, & Chmitorz, 2008; Wichers et al., 2012). In an
44
45 assessment of participants with and without depression, self-reported daily activity was
46
47 not associated with negative affect in either group (Mata et al., 2012). Methodological
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49 limitations, such as the self-reporting of physical activity and the insensitivity of affect
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51 measures (i.e., in detecting short-term fluctuations in affect) may explain the non-
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53 significant findings in some of these studies.
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3 Positive affect has been studied less frequently, with some studies demonstrating
4 that self-reported episodes of activity are associated with increased positive affect
5 (Fortier, Guerin, Williams, & Strachan, 2015; Hyde et al., 2011 ; Kanning & Schlicht,
6 2010; Maher et al., 2013; Mata et al., 2012; Wichers et al., 2012). This finding is
7 corroborated by two studies showing a within-person association between increases in
8 activity objectively measured via accelerometers and improved positive affect within or
9 across days (Kanning, 2013; Schwerdtfeger et al., 2008). Moreover, a few studies in
10 everyday life have provided initial evidence that activity is linked to less fatigue
11 (Kanning, 2013; Kanning et al., 2015).
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24 *The present study*

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26 To date, only a few studies have provided evidence on the association between activity
27 and negative/positive affect on the within-person level in everyday life. Many of the
28 available within-person studies focus on momentary activity effects (within one day or
29 across only a few days; e.g., Kanning, 2013; Schwerdtfeger et al., 2008; Wichers et al.,
30 2012) although national and international activity recommendations refer to a daily
31 activity level (i.e., 30 minutes of moderate activity 5 days per week; American Health
32 Association, 2014; European Working Group, 2008). Whether this recommended daily
33 activity level is associated with improved affect has rarely been studied so far (for
34 exceptions, see Gawrilow et al., 2016). However, evidence of daily activity effects on
35 affect can help to further promote activity programs. Thus, the present study
36 investigates daily levels of objectively recorded activity across 10 study days.
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50 Regarding the assessment of affect, the effects of activity have mostly been
51 studied for either negative or positive affect (e.g., Gawrilow et al., 2016; Langguth et
52 al., 2016; Maher et al., 2013). However, subjective experiences and theoretical
53 arguments favour a more nuanced picture of affect beyond just negative and positive
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3 affect. For example, Posner, Russell, and Peterson (2005) distinguished between
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5 unpleasant-deactivated (e.g., depressed affect, fatigue), unpleasant-activated (e.g.,
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7 angry, anxious affect), pleasant-activated (e.g., vigor) and pleasant-deactivated (e.g.,
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9 serenity) affects. The few existing studies assessing both positive and negative affect
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11 (e.g., Mata et al., 2012; Schwerdtfeger et al., 2008; Wichers et al., 2012) did not
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13 differentiate between unpleasant and pleasant affects of varying activation levels (e.g.,
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15 angry vs. depressed affect, vigor vs. serenity) or assessed physical activity with
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17 subjective reports (Hyde et al., 2011). By assessing affect in a more nuanced way, the
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19 present study extends past results by elucidating how activity is associated with specific
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21 affects.
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25 26 ***Hypotheses and contributions of the present study***

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28 The present study investigated whether objectively assessed moderate-to-vigorous
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30 physical activity (from now on referred to as *activity*) in young adults throughout the
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32 day is associated with same-evening affect within persons. We expected more activity
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34 than usual on a given day to be associated with less negative affect (i.e., depressed,
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36 angry, and anxious affect) and higher positive affect (i.e., vigor, serenity) on the same
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38 evening. Moreover, we explored whether more activity than usual on a given day is
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40 associated with fatigue.
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44 With these research questions, this study promises to address two main gaps in
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46 the current literature. First, the study findings are relevant for informing existing
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48 national and international guidelines (American Health Association, 2014; European
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50 working group, 2008) that recommend daily physical activity although few studies have
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52 actually examined the effects of daily activity. Prior evidence is mainly based on cross-
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54 sectional, longitudinal or intervention studies. By studying the effect of daily physical
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56 activity on evening affect, we will further add to the evidence base for these
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3 recommendations of daily activity. Second, another novel aspect of our study is the
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5 assessment of both positive and negative affect with varying levels of activation.
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7 Investigating the associations between objectively measured activity and specific
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9 unpleasant and pleasant affects of varying activation levels will reveal whether and how
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11 daily activity can serve as a tool for improving affect and thus, support effective health
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13 promotion.
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16 17 18 **Methods**

19 20 21 *Design and sample*

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23 In this intensive longitudinal study, young adults ($N = 189$) wore accelerometers and
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25 filled out daily diaries over 10 consecutive days¹. Initially, 192 participants enrolled in
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27 the study; three participants were excluded due to technical problems with the
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29 accelerometer, non-completion of any diary entries or withdrawal from the study,
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31 resulting in 189 participating young adults (71% women, age: $Mdn = 23.00$,
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33 interquartile range = 7.00). The sample was highly educated, with nearly all participants
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35 holding a university entrance qualification (94%) and many enrolled as university
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37 students (76%). The present sample showed no elevated level of depressed affect
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39 (10.5% of participants above the cut-off point, comparable to 12% in a representative
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41 community sample; Hautzinger, Bailer, Hofmeister, & Keller, 2012) and had normal
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43 weight (body mass index: $M = 22.28$, $SD = 2.61$; normal weight range: 18.50-24.90;
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45 WHO, 2006). Participants were recruited in two data collection waves in Autumn 2013
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47 and 2014 via flyers at a university in Germany as well as via word-of-mouth
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49 advertisement. All participants gave written informed consent to participate and
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56 ¹ Ten days were chosen as study period to gain representative data across one full week
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58 including the weekend.
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3 received a €5 voucher or university credits for their participation. The study was
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5 approved by a national ethics review board (i.e., German Psychological Society).
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7

8 9 *Procedure*

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11 Using an intensive longitudinal design, we assessed activity continuously and affect
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13 states with daily evening diaries across 10 consecutive days. On Study Day 1 (i.e.,
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15 Monday or Tuesday for most participants), participants met in small groups with two
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17 trained experimenters who summarized study procedures and measured participants'
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19 height and weight. At that point, each participant was provided with an accelerometer
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21 and activity measurement started. The study lasted until Study Day 10 (i.e., Wednesday
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23 or Thursday of the following week for most participants). Participants were instructed to
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25 wear the accelerometer during waking and sleeping hours but to remove it during water-
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27 based activities. The accelerometer was attached with a belt to participants' waistbands
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29 on the non-dominant side, ensuring valid measurement (McMinn, Acharya, Rowe,
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31 Gray, & Allan, 2013). On Study Day 1, participants received links to the online
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33 background questionnaire and to the first evening diary via email or text message,
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35 depending on their preference. Over the course of the study, they received daily links
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37 for the evening diaries. Participants were instructed to answer them right before going
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39 to sleep (i.e., Study Days 2 to 9).
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45 46 *Measures*

47 48 *Daily physical activity*

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50 This study focused on moderate-to-vigorous physical activity, which was measured
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52 continuously with triaxial accelerometers (4.6cm x 3.3cm x 1.5cm; model GT3X+;
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54 ActiGraph®, Pensacola, FL, US) at a sampling rate of 60 Hz. Raw data were band-pass
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3 filtered with a frequency range of 0.25 to 2.50 Hz to detect normal human motion and
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5 aggregated into 60s-epochs using ActiLife 6 ®. To identify whether participants
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7 actually wore the accelerometer, we used a recently improved algorithm to distinguish
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9 between wear and non-wear time. Non-wear time refers to time intervals with
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11 consecutive zero counts for at least 90 min, while allowing up to 2 min of activity if no
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13 counts were detected during the 30 min both upstream and downstream of that interval
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15 based on records of the accelerometer's vertical axis (Choi, Liu, Matthews, &
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17 Buchowski, 2011). Wear-time validated data was scored with regard to cut-off points
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19 based on a vector magnitude that takes records on all three axes into account. This
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21 scoring resulted in a measure of participants' daily number of minutes spent in
22
23 moderate-to-vigorous physical activity (> 2691 counts per minute; Sasaki, John, &
24
25 Freedson, 2011). Participants with at least six hours of accelerometer wear time
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27 between filling out the morning² and evening diary entries (see Kühnhausen, Leonhardt,
28
29 Dirk, & Schmiedek, 2013) and with at least four valid days out of eight study days were
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31 included in the analyses. When entries were missing, the mean time at which the
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33 participant made morning or evening diary entries was taken as the cut-off for the daily
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35 accelerometer wear time calculation.
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42 *Daily affect*

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44 Participants rated their current evening affect³ using the *Profile of Mood States-15*
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50 ² Apart from the evening diaries, we also asked participants to fill out morning diaries.

51 However, the current study focuses solely on evening affect assessed in the evening
52 diaries.
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54 ³ Mood refers to “an affective state of long duration, low intensity, and a certain diffuseness”
55 (Frijda, 2009, p. 258) and the original version of the Profile of Mood States (McNair, Lorr
56 & Droppleman, 1992) instructs participants to answer how they felt during the last week
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3 (POMS-15; Cranford et al., 2006; McNair, Lorr, & Droppleman, 1992). We used a
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5 shortened version of the original POMS designed for repeated daily assessments to
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7 reliably detect within-person changes (Cranford et al., 2006). Participants answered
8
9 each item (“How do you feel right now?”) on a 5-point scale ranging from 1 (*not at all*)
10
11 to 5 (*extremely*). The POMS-15 includes five affect scales with three items each:
12
13 depressed affect (*sad, hopeless, discouraged*), angry affect (*angry, resentful, annoyed*),
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15 anxious affect (*anxious, on edge, uneasy*), vigor (*vigorous, cheerful, lively*), and fatigue
16
17 (*fatigued, worn out, exhausted*). In order to take pleasant-deactivated affect into
18
19 account, we also included a scale to assess serenity (*relaxed, calm, at ease*; Cohen,
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21 Doyle, Turner, Alper, & Skoner, 2003). Mean scores for each individual and each affect
22
23 scale were calculated.
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27 For all affect scales, we computed reliability estimates on the between-person
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29 level (i.e., referring to the reliability of individual differences in affect across study
30
31 days), and on the within-person level (i.e., referring to the reliability of day-to-day
32
33 affect fluctuations; Shrout & Lane, 2012). For evening affect, reliabilities on the
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35 between/within-person level were as follows: .94/.76 (depressed affect), .94/.83 (angry
36
37 affect), .94/.66 (anxious affect), .96/.73 (vigor), .94/.71 (serenity) and .96/.76 (fatigue).
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39 These reliability estimates are in line with previously reported findings (e.g., Cranford
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41 et al., 2006).
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53 including today. In contrast, affect can be seen as “a neurophysiological state that is
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55 consciously accessible as a simple, nonreflective feeling” (Russell, 2003, p. 147). This
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57 means that affect and mood can be differentiated by their temporal course. Therefore in
58
59 this study we refer to affect since we measured current affect in daily life.
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Data analyses

Data preparation

We used activity and affect assessments from Study Days 2 to 9 (i.e., full study days). Days 1 and 10 were excluded because participants had to get used to wearing the accelerometer on the first day and brought back the accelerometer at individually selected time points on Day 10. Before analysing the diary data, we checked whether the time stamps registered online for each diary entry were in line with study protocol, as recommended (e.g., Shiffman, Stone, & Hufford, 2008). As participants were instructed to answer evening diaries before going to sleep, we considered all entries registered before 5:00 a.m. the next day as valid.

Within-person association between activity and evening affect

As a result of our intensive longitudinal design, repeated assessments are nested within participants. Thus, to analyze the within-person association between daily activity and same-evening affect, we used multilevel models (also called mixed-effects models, e.g., Singer & Willett, 2003). Random slope models were calculated for each affect scale to test for a within-person association between activity and evening affect. We centered all time-varying variables at both the grand mean and the person mean, respectively, to decompose the effects of time-varying variables (e.g., daily activity) into their stable between-person part (e.g., $Activity-B_i$ indicates individual i 's trait-like tendency to be more physically active than other participants) and their time-varying within-person part (e.g., $Activity-W_{it}$ indicates individual i 's state tendency on day t to be more physically active than usual). Equation 1 expresses a composite multilevel regression for testing our hypotheses:

$$Affect_{ti} = (\gamma_{00} + u_{0i}) + (\gamma_{10} + u_{1i}) Day_{ti} + \gamma_{11}WearTime_{ti} + \gamma_{01}Activity-B_i + (\gamma_{12} + u_{2i}) Activity-W_{ti} + \varepsilon_{it} \quad (1)$$

Evening affect of a participant i on day t is predicted by the following five fixed effects: (a) an intercept of affect, γ_{00} ; (b) an average linear time trend indicating the change in affect over the study days, centered on Day 3, γ_{10} ; (c) the participant's accelerometer wear time on a given day, γ_{11} ; (d) the average activity of each participant across all study days, γ_{01} ; and (e) the daily within-person fluctuation of each participant around their individual average activity, γ_{12} . Additionally, three random effects are included with mean 0 and variance u that account for individual shifts from the sample's average: (a) participant's deviation from the average intercept, u_{0i} ; (b) participant's deviation from the average time trend, u_{1i} ; and (c) participant's deviation from the average activity slope, u_{2i} . Importantly, the activity predictor on the within-person level tests the hypothesis that participants who engaged in more activity than usual over the course of one day ($\gamma_{12} + u_{2i}$) show enhanced same-evening affect ($Affect_{ti}$). To account for the longitudinal data structure, we modeled time dependence of the residuals with a first-order autoregressive structure (*ARI*; Singer & Willett, 2003). All models were calculated with maximum likelihood estimation analyses and with a probability level of $p < .05$ to indicate significance using IBM SPSS Statistics 22 ®. The SPSS syntax used for the analyses is given in Appendix A.

Results

Compliance

Of 1,512 possible observations (i.e., 189 participants x 8 study days), we analyzed 1,377 observations with valid daily assessments of activity, and evening affect. Overall, participants showed high compliance in terms of wearing accelerometers and filling out

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2
3 diary entries. Most participants (92%, $n = 173$) had a complete set of valid
4
5 accelerometer wearing days from Study Day 2 to 9. On a valid day, participants wore
6
7 the accelerometer for 14.12 hours ($SD = 1.23$) on average. With regard to valid diary
8
9 entries (i.e., entries with time stamps in line with the study protocol), participants
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11 answered on average 7.40 evening diaries out of 8.00 possible entries. In addition, 86%
12
13 of participants had at least 7 of 8 valid evening diary entries. On average, evening
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15 diaries were answered at 11:00 p.m. ($SD = 62$ min). In sensitivity analyses, we found no
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17 significant correlation above $r = .12$ (all $p > .05$) between any one indicator of valid
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19 observations and various background as well as daily assessed variables.
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23 24 *Descriptives statistics*

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26 To highlight the different levels of aggregation, descriptive statistics are presented in
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28 Table 1 separately for the between-person and within-person levels. The intraclass
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30 correlation coefficient (ICC) indicates how much of the variance originates on the
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32 between-person level and thus allows inferences to be made about the degree of
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34 variance attributable to within-person variation and a residual term (i.e., $1 - ICC$). For
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36 all affect variables, at least 50% of variability cannot be accounted for by individual
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38 differences between persons, but occurs due to within-person variation and residual
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40 error, thus calling for multilevel analyses. For daily activity assessed with
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42 accelerometers, 77% of variability (i.e., $1 - 0.23$) occurs due to fluctuations within
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44 persons and residual error. On average, participants reported moderate levels of vigor
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46 and fatigue and relatively low levels of anxious, angry and depressed affect in the
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48 evening diaries. Variability in affect ratings was present at the between-person and
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50 within-person levels, indicating that there were individual differences in mean affect
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52 ratings across the study period as well as fluctuations in each person's affect ratings
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54 from day to day. In total, participants engaged in about one hour of activity per day
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3 (59.19 min). The typical person's activity levels changed considerably from day to day
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5 (pooled within-person standard deviation for activity: $SD = 31.60$ min/day). [Table 1
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7 near here]
8
9

10 ***Within-person association between activity and evening affect***

11
12 Consistent with our hypotheses, we found significant negative within-person
13
14 associations between activity and depressed as well as angry same-evening affect. On
15
16 days where participants showed a 60-min increase in activity over their person mean,
17
18 they also reported less depressed and less angry affect (both $\gamma_{12} = -0.06$). Surprisingly,
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20 more activity than usual was not significantly associated with less anxious same-
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22 evening affect.
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26
27 In line with our hypotheses, we found significant positive within-person
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29 associations between activity and vigor as well as serenity in the evening. On days when
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31 participants showed a 60-min increase in activity over their person mean, they also
32
33 reported more vigor ($\gamma_{12} = 0.07$) and more serenity ($\gamma_{12} = 0.10$).
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37 Interestingly, more activity than usual was associated with higher same-evening
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39 fatigue. With a 60-min increase in activity over a participant's person mean, same-
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41 evening fatigue increased by 0.09 points (γ_{12}). Activity was also linked to evening
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43 fatigue on the between-person level. Participants who typically engaged in 60-min more
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45 activity than others showed 0.29 points (γ_{01}) less evening fatigue on average. In
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47 sensitivity analyses, we tested for effects of gender, age and weekday. There were no
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49 main effects of these variables in predicting evening affect, nor did they moderate the
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51 effects of activity on affect. Thus, we report the more parsimonious models without
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53 these covariates in Table 2. [Table 2 near here]
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Discussion

This intensive longitudinal study in young adults showed that daily activity matters for affective well-being and thus supports national and international guidelines (American Health Association, 2014; European working group, 2008) recommending daily physical activity while few prior studies have actually examined the effects of daily activity. Using a strong research design including objectively assessed activity and daily online reports of positive and negative affect, the study found evidence that daily activity is associated with improved affect in the evening at the within-person level. On days when participants engaged in more activity than usual, they reported less depressed and less angry affect in the evening, but not less anxious affect. In addition, participants reported more vigor and more serenity in the evening on days with more activity than usual. Exploratory analyses showed that more activity than usual was linked to more same-evening fatigue.

First, our findings on the anti-depressant and anger-reducing associations of activity corroborate previous evidence from cross-sectional, longitudinal, and intervention studies (e.g., Conn, 2010; Mammen & Faulkner, 2013; Parfitt, Rose, & Markland, 2000; Poole et al., 2011; Puetz, O'Connor, & Dishman, 2006; Rimer et al., 2012), while often no significant association was found in within-person studies of adults (e.g., Giacobbi, Hausenblas, & Frye, 2005; Hyde et al., 2011; Kanning, 2013, et al., 2015; Liao et al., 2015; Mata et al., 2012; Schwerdtfeger, et al., 2008; Wichers et al., 2012). In line with studies in adolescent samples (e.g., Gawrilow et al., 2016; Langguth et al., 2016), the within-person effects of activity in the present study were relatively small. Importantly, even low levels of negative affect are relevant, as the measures for depressed and angry affect were designed to capture relatively intense negative affect (i.e., by introducing such items as *hopeless* or *resentful*). The generally low levels of negative affect in this healthy sample of young adults may account for the relatively

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2
3 small effects. However, the small effects in this study, found in everyday life and over
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5 the course of one day, may still be relevant, as experiences of slightly reduced negative
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7 affect could accumulate over time and have long-term implications for well-being. In
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9 contrast to the within-person associations between activity and the two negative affect
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11 scales depressed and angry affect, daily activity was not linked to anxious affect. This
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13 lack of a within-person association may be attributed to the relatively low within-person
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15 fluctuations in anxious evening affect (see Table 1).
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19 For positive affect, we found evidence for a within-person association between
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21 activity and positive same-evening affect: more activity than usual was associated with
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23 more vigor and more serenity. These findings are in line with prior studies in everyday
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25 life (e.g., Fortier et al., 2015; Hyde et al., 2011; Kanning, 2013; Kanning & Schlicht,
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27 2010; Maher et al., 2013; Mata et al., 2012; Schwerdtfeger et al., 2008; Wichers et al.,
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29 2012). Importantly, previous studies reporting significant within-person associations
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31 between physical activity and positive affect used sampling plans where participants
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33 indicated their momentary affect directly after being physically active (e.g., Kanning,
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35 2013; Schwerdtfeger et al., 2008) and often did not differentiate between positive
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37 affects with varying levels of arousal (i.e., vigor vs. serenity; e.g., Mata et al., 2012;
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39 Schwerdtfeger et al., 2008; Wichers et al., 2012). Thus, the present findings yield first
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41 insights into daily activity effects and provide support for its benefits with regard to
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43 specific positive affects (i.e., vigor and serenity). However, an everyday life study with
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45 a small middle-aged adult sample and longer time lags between assessments (i.e.,
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47 activity during the preceding 6 hours before affect measure) did not find a consistent
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49 association between activity and positive affect (Stavrakakis et al., 2015). Therefore,
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51 further replication studies in young adults are needed.
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3 For fatigue, exploratory analyses revealed contrasting associations between
4 activity and evening fatigue depending on the level of aggregation: (1) On the within-
5 person level, days with more activity than usual were associated with higher same-
6 evening fatigue, whereas (2) on the between-person level, participants who typically
7 engaged in more activity than others reported less evening fatigue. First, our within-
8 person finding is in contrast to some studies in everyday life that have found less fatigue
9 but more energy after activity (e.g., Kanning, 2013). However, we assessed fatigue on a
10 unipolar scale that might have teased apart feelings of energy and fatigue. In addition,
11 higher evening fatigue after activity could benefit sleep quality (Kredlow, Capozzoli,
12 Hearon, Calkins, & Otto, 2015) and thus be interpreted as a positive activity effect.
13 Second, our finding of a fatigue-reducing association of activity on the between-person
14 level could be due to the fact that regular activity leads to less overall fatigue, as has
15 been shown in intervention studies (e.g., Puetz et al., 2006), possibly attributable to the
16 higher fitness levels of regular exercisers. Consequently, these contrasting associations
17 impressively demonstrate that effects have to be disentangled at the within- and
18 between-person levels in order to gain deeper insight into the nature of the activity-
19 affect association.

20 21 22 *Limitations and directions for future studies*

23 This study has several limitations. First, inferences about a causal effect of activity in
24 terms of enhancing affect cannot be derived from the present study. Its intensive
25 longitudinal design allowed us to detect an activity-affect association within persons
26 that ruled out stable individual differences as alternative explanations of the association.
27 The study also established temporal order, with daytime activity predicting evening
28 affect. This study provides evidence for the promise of future intervention studies in this
29 age group; these studies could establish a causal effect of activity by experimentally
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3 increasing activity on specific days with adequate washout periods following these
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5 activity days and thus rule out time-varying alternative explanations of the within-
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7 person activity-affect association found in this study. Second, questions about the
8
9 underlying mechanisms linking activity and affect within persons remain unanswered
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11 and were beyond the scope of the current study. The next step in this research program
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13 is to study potential mechanisms for activity effects on affect in daily life, including
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15 psychological pathways (e.g., higher self-efficacy and self-esteem), physiological
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17 processes (e.g., lowered arousal, favorable hormonal changes), and social processes
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19 (e.g., social support and companionship) as well as the timing of these processes.
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22 Moreover, future studies should also take into account the physical and social context in
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24 which activity is performed and affect is assessed, as highlighted in previous studies
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26 (e.g., indoor vs. outdoor, alone vs. with others: Dunton, Liao, Intille, Huh, & Leventhal,
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28 2015; leisure vs. non-leisure time: Kanning, 2013). Third, distributions of negative
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30 affect variables are skewed. Future research should use items that differentiate lower
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32 intensities of negative affect. Fourth, our sample showed an elevated mean level of
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34 activity ($M = 59$ min/day) compared to representative US and German adult samples
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36 (i.e., $M = 32$ min/day; Troiano et al., 2008; Lampert, Mensink, & Mütters, 2012). Thus,
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38 our sample of young adults seems to be not representative, meaning that our findings
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40 may not generalize to other populations differing in age or socio-economic status.
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42 However, the age group at hand is highly relevant because of elevated negative affect
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44 during young adulthood (Stone et al., 2010).
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51 ***Implications for health promotion***

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53 Based on the present findings, important implications for health promotion can be
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55 derived. First, more activity than usual over the course of a day is associated with less
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57 depressed and less angry evening affect as well as more vigor and more serenity in
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3 young adults. Thus, physical activity may be further emphasized as a health promotion
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5 strategy (WHO, 2006) for managing unpleasant and pleasant affects of varying
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7 activation levels. Meeting the daily activity recommendations for physical health can
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9 also boost mental health as measured by improved evening affect. Thus, health
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11 promotion programs related to increased activity should target young adults, who often
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13 experience increased levels of negative affect and lower levels of positive affect
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15 (Carstensen et al., 2011; Stone et al., 2010). This can easily be implemented by, for
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17 instance, supporting young adults' regular participation in community and university
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19 exercise programs. Furthermore, daily levels of physical activity can be increased via
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21 action planning (Sniehotta, Scholz, & Schwarzer, 2005) and self-regulation strategies
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23 (e.g., implementation intentions; Stadler, Oettingen, & Gollwitzer, 2009; monitoring
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25 and feedback; Prestwich, Conner, Hurling, Ayres, & Morris, 2016) that can be tailored
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27 to individual needs.
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32 33 **Conclusion**

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35 To our knowledge, this is the first study in everyday life with a young adult sample
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37 demonstrating that days with more activity than usual were associated with less
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39 negative evening affect and more positive evening affect. Results are based on objective
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41 assessments of physical activity and on time-stamped online measures of affect, thus
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43 extending previous research using self-reported physical activity or paper-and-pencil
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45 assessments of affect by presenting a more valid database (Kanning et al., 2013). In
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47 light of young adults' increased risk of experiencing negative affect and low levels of
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49 positive affect in everyday life, our findings that persons can potentially influence their
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51 affect with activity is highly encouraging. Consequently, increasing young adults'
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53 physical activity could represent an important component of health promotion programs
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55 related to affective well-being as well as long-term health and may be an easily
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accessible intervention.

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Table 1. Descriptive statistics of main variables.

Variables	<i>Between-person variability</i>				<i>Within-person variability</i>			
	ICC	<i>N</i>	<i>M</i>	<i>SD</i>	Empirical range	<i>n</i>	<i>SD</i>	Empirical range
<i>Evening affect [1-5]</i>								
Depressed affect	0.32	189	1.29	0.37	1.00-2.90	1394	0.34	0.00-1.33
Angry affect	0.24	189	1.26	0.33	1.00-2.88	1393	0.36	0.00-1.41
Anxious affect	0.39	189	1.30	0.37	1.00-2.88	1393	0.31	0.00-1.51
Vigor	0.46	189	2.48	0.66	1.00-5.00	1395	0.62	0.00-1.41
Serenity	0.36	189	3.18	0.60	1.67-4.71	1395	0.67	0.00-1.57
Fatigue	0.39	189	2.74	0.69	1.08-4.56	1396	0.72	0.00-1.46
<i>Activity (min)</i>	0.23	189	59.19	22.46	19.38-141.25	1483	31.60	8.07-103.37

Note. ICC: intra-class correlation, Evening affect: assessed on a scale from 1 (*not at all*) to 5 (*extremely*), Activity: moderate-to-vigorous physical activity.

Table 2. Multilevel models to test the within-person association between activity and evening affect.

	Depressed affect	Angry affect	Anxious affect	Vigor	Serenity	Fatigue
<i>Fixed effects</i>						
Intercept, γ_{00}	1.30**	1.26**	1.33**	2.51**	3.30**	2.80**
Day, γ_{10}	-0.005	-0.001	-0.01*	-0.01	-0.05**	-0.02*
Wear time (hrs), γ_{11}	-0.01	-0.001	0.004	-0.02*	-0.01	0.04**
Activity, between (hrs), γ_{01}	-0.11	-0.09	-0.07	-0.06	-0.09	-0.28*
Activity, within (hrs), γ_{12}	-0.06*	-0.06*	-0.03	0.07*	0.10**	0.09*
<i>Random effects</i>						
Intercept, σ^2_0	0.09**	0.06**	0.10**	0.35**	0.27**	0.36**
Day, σ^2_1	0.001	0.001	0.001†	0.001	0.003	n. e.
Activity, within (hrs), σ^2_2	n. e.	0.005	n. e.	n. e.	0.003†	0.01
Residual, ε_{it}	0.22**	0.23**	0.17**	0.46**	0.49**	0.60**
AR1 ρ	0.14**	0.12**	0.15**	0.14**	0.09*	0.11**

Note. $N = 189$ participants across 8 consecutive days, $n = 1,377$ valid observations, Activity: moderate-to-vigorous physical activity, n. e.: not estimable; between-person predictors centered at the grand mean, within-person predictors centered at the person mean, Day: centered on Day 3, estimates for fixed effects are unstandardized regression coefficients, ML estimation, ** $p < .01$, * $p < .05$, † $p < .10$.

APPENDIX A**Syntax used for main analyses in SPSS**

Syntax for multilevel models to test the within-person association between activity and evening affect (Hypotheses):

```
MIXED Evening affect WITH Day WearTime Activity_B Activity_W
```

```
/FIXED= Intercept Day WearTime Activity_B Activity_W
```

```
/METHOD=ML
```

```
/PRINT= G R SOLUTION TESTCOV
```

```
/RANDOM= INTERCEPT Day Activity_W | SUBJECT(ID) COVTYPE(DIAG)
```

```
/REPEATED=Day | SUBJECT(ID) COVTYPE(AR1).
```