Momentary Affect Predicts Bodily Movement in Daily Life: An Ambulatory Monitoring Study

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There is converging evidence that physical activity influences affective states. It has been found that aerobic exercise programs can significantly diminish negative affect. Moreover, among healthy individuals, moderate levels of physical activity seem to increase energetic arousal and positive affect. However, the predictive utility of affective states for bodily movement has rarely been investigated. In this study, we examined whether momentarily assessed affect is associated with bodily movement in everyday life. Using a previously published data set (Schwerdtfeger, Eberhardt, & Chmitorz, 2008), we reanalyzed 12-hr ecological momentary assessment (EMA) data from 124 healthy volunteers. Electronic momentary positive-activated affect (EMA-PAA) and negative affect (EMA-NA) were assessed via handheld computers, and bodily movement was recorded via accelerometers. Generalized linear mixed models were calculated. Results indicated that EMA-PAA increases were accompanied by bodily movement increases of varying intensity. EMA-NA was also positively associated with increases in certain kinds of bodily movement. In light of previous research, this finding suggests that affect and bodily movement may have circular effects on each other.

Keywords: Ambulatory monitoring, bodily movement, ecological momentary assessment, negative affect, physical activity, positive affect

There is cumulating evidence that physical activity has beneficial effects on affect. For example, Barbour, Edenfield, and Blumenthal (2007) reported in their review that exercise training appears to be beneficial for individuals with symptoms of depression and anxiety. In a similar vein, it has recently been shown that physical exercise programs have anxiolytic effects in randomized controlled trials (Wipfli, Rethorst, & Landers, 2008). Of note, even within nonclinical healthy participants, physical activity appears to be accompanied by changes in affective states. For
example, using a student sample, Watson (1988) found that daily exercise was significantly associated with daily positive affect; however, there was no reliable association with negative affect. Interestingly, there now appears to be evidence that even low-dose bodily movement might be associated with improvements in affect (e.g., Berger & Motl, 2000; Ekkekakis, 2003; Ekkekakis, Backhouse, Gray, & Lind, 2008; Ekkekakis, Hall, van Landuyt, & Petruzzello, 2000; Reed & Buck, 2009; Reed & Ones, 2006; Thayer, Peters, Takahashi, & Birkhead-Flight, 1993; Thayer et al., 2003). Of note, these studies highlight the importance of assessing different facets of affect to unveil associations with bodily movement. Taken together, there is evidence to suggest that even low-intensity episodes of physical activity may alter certain affective states (specifically, positive affective states and energetic arousal seem to increase, whereas tension and tiredness seem to decrease following low-dose physical activity).

Importantly, the relationship of physical activity and affect has mainly been investigated in controlled settings (e.g., laboratory assessment, physical activity courses), but it is not well understood how these associations unfold in everyday life (e.g., Bussmann, Ebner-Priemer, & Fahrenberg, 2009). Applying an ecological momentary assessment (EMA) design, Kanning and Schlicht (2010) recently showed that subjectively reported movement episodes in daily life (e.g., going for a walk, gardening) were accompanied by increases in energetic arousal, calmness, and valence. To overcome the problem of shared method variance when self-report measures are used to assess both bodily movement and affect, we recently conducted an ambulatory monitoring study with 124 healthy participants (Schwerdtfeger, Eberhardt, & Chmitorz, 2008) to examine whether the relationship of objectively assessed movement and affect can be observed in daily life as well. Physical activity was recorded throughout one day (12 hr) by means of accelerometers, and aspects of positive-activated affect and negative affect were assessed via handheld computers (personal digital assistants; PDAs). Our analytic strategy was to predict changes in affect from the amount of bodily movement exhibited in three different time windows before the assessment of affect (1 min, 5 min, and 15 min). Multilevel modeling revealed significant effects of bodily movement on positive-activated affect for each time window, whereas there was no significant relationship with negative affect. The effects were rather moderate in size, suggesting that a low-intensity walk could increase positive-activated affect by about 2–3 points on a scale ranging from 7 to 35, equaling an improvement in affect of approximately 6–9%. Nonetheless, our results were in line with evidence from previous studies suggesting that there are psychological benefits of engaging in bodily movement. Most importantly, our study showed that even everyday-life bodily movement (which is, for the most part, a low-intensity activity) might be considered a reliable modulator of affect.

In sum, these findings suggest reliable associations between bodily movement and positive-activated affective states. Although the majority of the studies on the relationship of physical activity and affect hypothesize that bodily movement directly influences affective states, this relationship need not to be unidirectional. In particular, it seems plausible to assume that an individual’s affect could also have an impact on bodily movement. Surprisingly few studies have investigated the role of affect on subsequently performed bodily movement. Some of the studies examined the effects of affect on bodily movement rather indirectly by assessing
personality dimensions that are linked to emotional processes and relating them to movement or physical activity parameters. For example, Volkers et al. (2002) found that harm avoidance (a tendency to respond intensely to signals of aversive stimuli) was negatively associated with 24-hr movement activity, whereas reward dependence (i.e., the tendency to respond intensely to signals of reward) predicted higher levels of movement activity. This pattern of result could be substantiated by a recent meta-analysis that found that neuroticism (which is closely related harm avoidance and negative affect) was moderately negatively associated, and extraversion (which is more closely linked with reward dependence and positive affect) was positively associated with physical activity (Rhodes & Smith, 2006), suggesting that the tendency to dispositionally exhibit positive or negative affect could modulate physical activity. Compatible with this rather indirect evidence is a study conducted by Hamid (1990). The author observed that negative affect the week before an exercise program was associated with lower program satisfaction and quicker dropout. Conversely, positive affect was related to higher satisfaction and slower dropout (for nonsignificant findings, however, see Yeung & Hemsley, 1997). Moreover, Herman et al. (2002) found that self-rated state anxiety among depressed patients predicted earlier dropout in an exercise treatment program and less improvement in depressive symptoms for those who remained in therapy. Although these studies suggest that negative affective states hinder exercise behavior and positive affective states facilitate exercise behavior, it should be mentioned that they do not allow direct tests of how actual affect is associated with the initiation or maintenance of spontaneous physical activity behavior in daily life. One recent study found that among overweight individuals, affect in the morning predicted the initiation of physical exercise throughout the day (Carels, Coit, Young, & Berger, 2007). Specifically, when participants exhibited positive affect in the morning, they were more likely to exercise, and when they exhibited negative affect, they were less likely to exercise. Hence, there is evidence to suggest that affective states could also impact the initiation and maintenance of physical activity performed in daily life.

We aimed to examine this association in more detail using our previously described data set. Since bodily movement was recorded continuously throughout the day, we were able to reanalyze the data to examine whether affective states predict subsequently assessed bodily movement. Importantly, in this study, we recorded bodily movement as exhibited in everyday life (including daily-life activities such as stair climbing, walking, cycling, etc.) and not necessarily physical exercise, which was the main outcome in various other studies (e.g., Carels et al., 2007; Hamid, 1990). We are aware that many of these activities might not qualify as physical activity, which is defined as bodily movement that substantially increases energy expenditure. To avoid conceptual confusion, we use the term bodily movement throughout this article when referring to daily life activities of different intensity. In addition, contrary to the study of Carels et al. (2007), we assessed both positive and negative affective states as suggested by Ekkekakis et al. (2000), and did not apply a unidimensional affect rating scale. In line with previous research, we expected that positive-activated affect is positively associated with subsequently performed bodily movement throughout a day. That is, higher levels of positive-activated affect should be related to higher levels of movement and vice versa. Moreover, we were interested in exploring whether negative affective states are also related to changes in bodily movement. Previous research, for example, has shown that
Momentary Affect and Bodily Movement

negative affect is associated with lower frequency of physical activity (e.g., Carels et al., 2007; Hamid, 1990; Herman et al., 2002). On the other hand, it has been found that negative affective states are positively related to bodily movement and posture (e.g., Wallbott, 1998), thus probably increasing daily life movement. Taken together, there appears to be no clear relationship between negative affective states and subsequently performed bodily movements. Therefore, we abstained from formulating clear-cut hypotheses for negative affective states.

Method

Participants

One hundred twenty-four healthy volunteers (64 women) participated in the study. The sample comprised 66% students, and 23% were employed. The remaining 11% were either unemployed or retired. They had a mean age of 31.67 years ($SD = 12.56$, range 18–73 years) and a mean body mass index (BMI) of 23.23 kg/m² ($SD = 3.14$). Participants were recruited through advertisements on the university campus and via oral communication. They were given course credit when applicable. The study was approved by an institutional review board.

Apparatus and Questionnaires

Bodily movement was recorded throughout a period of 12 hr by means of uniaxial accelerometers (Actigraph GT1M) attached to the ankle of the left foot (e.g., Guinhouya, Hubert, Dupont, & Durocher, 2005). The Actigraph is a well-validated device with sufficient reliability (e.g., Matthews, Ainsworth, Thompson, & Basset, 2002; Trost, McIver, & Pate, 2005). Its validity has been documented in a number of studies. For example, bodily movement as assessed via the Actigraph is substantially associated with energy expenditure and oxygen uptake (for an overview, see Trost, McIver, & Pate, 2005). Activity was sampled at 30 Hz and stored in memory for each minute. The sensitivity of the device ranges from approximately 0.05 to 2.00 $g$ (gravitation) and the relevant measure is counts per minute. To facilitate interpretation of the data, it should be noted that slow walking results in approximately 5,000 counts/min and climbing stairs results in approximately 7,000–8,000 counts/min. We applied EMA to assess various positive and negative affective states throughout the day. Therefore, 14 adjectives were presented via PDAs (Palm Zire31) using the software DialogPad (Gerhard Mutz, University of Cologne, Germany): active, awake, dynamic, powerful, exhausted, tired, relaxed, lively, nervous, depressed, stressed, irritable, content, and happy. Adjectives were presented in a pseudo-randomized order and rated on a Likert-type scale ranging from 1 (not at all) to 5 (very much so). Each PDA entry was supplied with a time stamp, which permits precise matching with the corresponding Actigraph readings.

Moreover, the German version of the positive and negative affect schedule (PANAS; Krohne, Egloff, Kohlmann, & Tausch, 1996; Watson et al., 1988) was completed in the evening of the recording day. Participants were asked to rate how they felt during the recording day. Positive affect (PA) and negative affect (NA) were reliably assessed (Cronbach’s $\alpha = .88$ for PA and .84 for NA). In addition, participants were asked to rate the typicality of the day on a 4-point rating scale.
(1 = absolutely typical, 2 = rather typical, 3 = rather atypical, 4 = totally atypical). Sixty-six percent of the sample reported that the recording day was absolutely typical or rather typical and 32% reported that the recording day was rather atypical. The remaining 2% rated the day as being absolutely atypical.

Procedure

Upon arriving at the laboratory, informed consent was obtained and participants were told that they could discontinue participation at any time without giving a reason. They were instructed to choose a typical weekday for participation and were requested to arrive at the laboratory in the morning between 9 and 10 a.m. (there were no recordings on a weekend). For some participants (specifically, those who were working full-time), it was inconvenient to appear at the laboratory, so the experimenter took the equipment to the participant’s home. Participants were familiarized with the study protocol and the technical equipment. Subsequently, the accelerosensor was attached to the left ankle and the PDA was initialized. PDA entries were signal contingent, and were to be made following an acoustic signal (beep). The signal was initialized about every hour with a random component of 15 min to prevent expectancy effects. If participants were not able to respond to the signal, they could ignore it and initialize the PDA later when more appropriate. Overall, 1,447 valid entries were obtained (approximately 12 entries for each participant). Recording ended in the evening at 10 p.m. Participants were instructed to complete the PANAS and some questionnaires on demographic variables and to detach the accelerosensor after 10 p.m. They were instructed to return the equipment to the laboratory the next morning. On account of the sensitive technical equipment, participants were not allowed to engage in bathing or showering during recording time.

Data Analysis

To assure accurate timing of the PDA and the accelerosensor, both devices were synchronized weekly using commercial computer software (timeAdjust, Stevens Creek Software). Regular checkups revealed that deviations in time were less than 7 s after 7 days. Upon completion of each recording, PDA ratings were transferred to a computer. Bodily movement was parametrized following each affect entry. We averaged bodily movement across four time windows (1 min, 1–5 min, 1–15 min, and 1–30 min after assessment of affect) to allow for the examination of short-term and medium-term activity changes after each assessment of affect. To overcome possible noncompliance (i.e., zero activity counts possibly indicating that the participants did not wear the accelerosensor properly throughout the day), we aimed to exclude low-activity counts in a second set of analyses. Previous research has suggested that Actigraph readings below 259 counts/min might be classified as sedentary periods (e.g., Matthews, 2005). Therefore, a high-pass filter of 260 counts/min was applied to exclude all sedentary periods. Moreover, in a final set of analyses, we were interested in examining the relationship between affect and sedentary periods, light activity, moderate activity, and vigorous activity, respectively. To accomplish this, we analyzed the proportion of minutes spent in sedentary (0–259 counts/min), light (260–759 counts/min), moderate (760–5,724 counts/min), and vigorous activity (>5,725 counts/min) throughout the 30 min after the
affect ratings. Thresholds were defined according to the study by Matthews (2005). It should be noted that cutoff scores for Actigraph output have been validated for hip placement of the device. However, since we are not aware of cutoff scores for foot placement of the sensor, we relied on these values in our study.

Generalized linear mixed models (GLMM) were calculated to predict bodily movement in the four time windows from the preceding affect ratings. Because bodily movement was not normally distributed in this sample (there was over-dispersion with many individuals showing low levels of movement; i.e., for the 1-min time window: $M = 542.18$ counts/min, $SD = 1,285.31$, $Min = 0.00$, $Max = 11,838.00$; for the 5-min time window: $M = 654.02$ counts/min, $SD = 1,236.97$, $Min = 0.00$, $Max = 9,771.80$; for the 15-min time window: $M = 724.96$ counts/min, $SD = 1,239.65$, $Min = 0.00$, $Max = 10,383.30$; for the 30-min time window: $M = 771.74$ counts/min, $SD = 1,195.66$, $Min = 0.00$, $Max = 9,849.80$), we performed Poisson GLMMs with penalized quasi-likelihood approximation (PQL). In addition, we controlled for bodily movement exhibited 15 min before the assessment of affect to rule out carry-over effects of bodily movement on affect. Bodily movement exhibited 15 min before the assessment of affect was divided by 1,000 to facilitate interpretation of the regression coefficients. Affect ratings were centered before analyses. Moreover, we included age and BMI as continuous predictors (grand-mean centered) as well as sex ($0 = \text{men}$, $1 = \text{women}$).

Models were specified with participants as a random effects variable. Moreover, we allowed random variation with respect to positive affective states, thus explicitly allowing heteroskedasticity with respect to positive affect for each individual. GLMMs were calculated using the open-source statistics software R (Version 2.10.1; R Development Core Team, 2009). We applied the program glmmPQL, attached to the MASS library (version 7.3–5; Venables & Ripley, 2003) and specified a continuous autoregressive error structure (CAR1) for the covariance matrix of the residuals, which handles unevenly spaced assessments more accurately than a first-order autoregressive error structure. In line with expectations, the continuous autoregressive error structure was highly significant for each time window, and the phi-coefficients varied between .72 and .94. Since PQL inference in GLMMs might lead to biased estimates (e.g., Bolker et al., 2009), we also applied the program lme4 (version 0.999375–32; procedure glmer; Bates & Sarkar, 2009), which makes use of the more robust Laplace approximation. Moreover, this program is able to handle more than one random effect, so we allowed random variation with respect to both positive and negative affective states. However, since lme4 is not (yet) capable of handling serial autocorrelations, we could not specify CAR1. Nonetheless, this alternative methodology was applied to test the robustness of the PQL-derived findings. We report regression coefficients ($b$; absolute effect size in ms), standard errors ($SE$), the $t$ or $z$ statistic, and $p$ values. For all comparisons the level of significance was fixed at $p < .05$ (two-tailed).

Results

Separating Positive from Negative Affective States

First, we applied common factor analysis to examine the factor structure of ambulatory assessed affect. Therefore, the first regular PDA assessment of each participant
was used. According to previous studies, two factors were expected to emerge: one factor representing positive affective states and one factor representing negative affective states (Yik, Russell, & Feldman-Barrett, 1999). We applied varimax rotation and extracted the factors according to a scree plot. This resulted in a three-factor solution, accounting for 57.2% of the variance. However, whereas the loadings for factor 1 and factor 2 were substantial and clearly interpretable, suggesting a simple structure, factor 3 showed mainly cross-loadings with the other two factors. Hence, we recalculated the factor analysis, this time explicitly extracting two factors. A varimax (orthogonal) rotation specifying a two-factor solution accounted for 48.4% of the variance. Table 1 depicts the rotated factor matrix. Items were grouped along two dimensions: ecological momentary assessed positive activated affect (EMA-PAA) with 6 items (lively, awake, active, powerful, dynamic, happy) and ecological momentary assessed negative affect (EMA-NA) with 5 items (nervous, stressed, irritable, depressed, relaxed [-]). Three items showed substantial cross-loadings (exhausted, tired, and content), and were therefore excluded from further analyses.

In a next step, we aggregated the respective items to yield a measure of EMA-PAA (6 items) and EMA-NA (5 items). Both scales showed acceptable reliabilities (Cronbach’s alpha for EMA-PAA: .90, Cronbach’s alpha for EMA-NA: .73) and were unrelated (r = -.11, ns) for the first regular assessment. Moreover, we calculated Pearson correlations with PA and NA of the PANAS. It was found that EMA-PAA was significantly positively related to PA (r = .59, p < .01) and moderately negatively related to NA (r = -.31, p < .01), whereas EMA-NA was

<table>
<thead>
<tr>
<th>Factor Loading</th>
<th>Factor 1: EMA-PAA</th>
<th>Factor 2: EMA-NA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lively</td>
<td>.857</td>
<td>-.036</td>
</tr>
<tr>
<td>Awake</td>
<td>.841</td>
<td>-.094</td>
</tr>
<tr>
<td>Active</td>
<td>.824</td>
<td>.063</td>
</tr>
<tr>
<td>Powerful</td>
<td>.809</td>
<td>-.109</td>
</tr>
<tr>
<td>Dynamic</td>
<td>.791</td>
<td>-.010</td>
</tr>
<tr>
<td>Exhausted</td>
<td>-.561</td>
<td>.412</td>
</tr>
<tr>
<td>Happy</td>
<td>.479</td>
<td>-.130</td>
</tr>
<tr>
<td>Tired</td>
<td>-.455</td>
<td>.383</td>
</tr>
<tr>
<td>Nervous</td>
<td>.114</td>
<td>.743</td>
</tr>
<tr>
<td>Stressed</td>
<td>.167</td>
<td>.636</td>
</tr>
<tr>
<td>Irritable</td>
<td>-.073</td>
<td>.609</td>
</tr>
<tr>
<td>Depressed</td>
<td>-.233</td>
<td>.597</td>
</tr>
<tr>
<td>Relaxed</td>
<td>.186</td>
<td>-.419</td>
</tr>
<tr>
<td>Content</td>
<td>.333</td>
<td>-.398</td>
</tr>
</tbody>
</table>

Table 1 Varimax Solution With Two Factors for Various Momentary Assessed Affective States

Note: 

aEigenvalue = 5.12, percent of variance = 33.51%.  

bEigenvalue = 2.61, percent of variance = 14.89%.
positively associated with NA ($r = .73, p < .01$) and moderately negatively associated with PA ($r = -.28, p < .01$).

The Relationship of Affect and Bodily Movement

The results of the GLMMs with PQL approximation for each time window for bodily movement (including sedentary periods) are shown in Table 2. There were significant effects of preaffect assessed movement levels on postaffect assessed levels for each time window ($b = 0.359$ for the 1-min time window, $b = 0.315$ for the 5-min time window, $b = 0.250$ for the 15-min time window, and $b = 0.180$ for the 30-min time window), documenting that bodily movement tended to remain stable from pre- to postaffect assessment. Moreover, EMA-PAA was significantly positively related to bodily movement for each of the four time windows ($b = 0.049$ for the 1-min time window, $b = 0.043$ for the 5-min time window, $b = 0.043$ for the 15-min time window, and $b = 0.042$ for the 30-min time window). These effects indicated that a 3-point increase in EMA-PAA on a scale ranging from 6 to 30 from the most recent affect assessment was accompanied by increases in bodily movement of approximately 13–16%, depending on the time window. Moreover, there were significant positive associations between EMA-NA and bodily movement for the 15-min time window ($b = 0.045$) and the 30-min time window ($b = 0.043$), suggesting that a 3-point increase in EMA-NA on a scale ranging from 5 to 25 was related to an increase in bodily movement by about 14% for both medium-term time windows. No other effects were significant.

Importantly, glmer-analyses applying the more robust Laplace approximation revealed similar findings. In particular, EMA-PAA was significantly positively associated with physical activity for the 5-, 15-, and 30-min time windows (5-min time window: $b = 0.073, z = 3.1$; 15-min time window: $b = 0.057, z = 2.8$; 30-min time window: $b = 0.054, z = 2.8$). However, the formerly significant effect for the 1-min time window was no longer significant ($b = 0.104, z = 1.4$). For EMA-NA, the effects for the 15- and 30-min time windows were also replicated (15-min time window: $b = 0.085, z = 2.1$; 30-min time window: $b = 0.068, z = 2.5$). Obviously, effect sizes were somewhat larger as compared with the potentially more biased PQL approximations. However, it should be emphasized that the latter analyses did not control for serial autocorrelation.

The Relationship of Affect and Bodily Movement Without Sedentary Periods

Moreover, we modeled bodily movement without sedentary periods. That is, activity counts that fell below 260 counts/min were discarded, leaving more intense movement episodes for analysis. Again, we applied GLMM models as well as the more robust glmer analysis with Laplace approximation. For reasons of parsimony, we report only the latter results. It turned out that the effects for both EMA-PAA and EMA-NA could be replicated for the 15-min and 30-min time windows, respectively. More specifically, EMA-PAA significantly predicted 15-min movement ($b = 0.031, z = 2.2$) and 30-min movement ($b = 0.034, z = 3.5$), and EMA-NA also significantly predicted 15-min movement ($b = 0.070, z = 2.6$). For the 30-min time window, the association of EMA-NA and bodily movement approached significance ($b = 0.024, z = 1.7$). No significant effects were found for the shorter time windows.
Table 2  Generalized Linear Mixed Effects (Poisson) Model of Physical Activity on Pre-Affect Bodily Movement, Ecological Momentary Assessed Positive-Activated Affect (EMA-PAA), and Negative Affect (EMA-NA) and Various Demographic Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>1 min</th>
<th>5 min</th>
<th>15 min</th>
<th>30 min</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>b</td>
<td>SE</td>
<td>t</td>
<td>b</td>
</tr>
<tr>
<td>Intercept</td>
<td>5.765</td>
<td>0.085</td>
<td>67.66**</td>
<td>6.156</td>
</tr>
<tr>
<td>Preaffect movement</td>
<td>0.359</td>
<td>0.020</td>
<td>18.17**</td>
<td>0.315</td>
</tr>
<tr>
<td>EMA-PAA</td>
<td>0.049</td>
<td>0.016</td>
<td>3.02**</td>
<td>0.043</td>
</tr>
<tr>
<td>EMA-NA</td>
<td>−0.005</td>
<td>0.017</td>
<td>−0.31</td>
<td>0.028</td>
</tr>
<tr>
<td>Sex</td>
<td>0.060</td>
<td>0.107</td>
<td>0.56</td>
<td>−0.066</td>
</tr>
<tr>
<td>Age</td>
<td>−0.003</td>
<td>0.005</td>
<td>−0.56</td>
<td>−0.003</td>
</tr>
<tr>
<td>BMI</td>
<td>−0.006</td>
<td>0.017</td>
<td>−0.34</td>
<td>−0.005</td>
</tr>
</tbody>
</table>

Note. Models with penalized quasi-likelihood approximations (PQL). For each model, a continuous autoregressive error structure (CAR1) was specified. The b estimates represent unstandardized partial regression coefficients.

†p < .10, *p < .05, **p < .01.
In addition, there was a significant effect of age for medium-term bodily movement ($b = -0.006$, $z = -2.0$ for the 15-min time window, and $b = -0.007$, $z = -2.6$ for the 30-min time window), indicating less movement with increasing age.

**Predicting Sedentary, Light, Moderate, and Vigorous Activity From Affective States**

The previous analyses suggested that both positive activated (EMA-PAA) and negative affective states (EMA-NA) were associated with increases in bodily movement throughout a day. However, these analyses could not show whether associations were dependent on the intensity of the activity performed. For example, one might argue that affect predicts only low to moderate levels of movement, but not more vigorous episodes of physical activity, thus questioning the clinical relevance of affect. Therefore, in a final set of analyses we aimed to predict bodily movements of different intensities from preaffect movement, affective states, and demographic variables. We calculated the percentage of activity exhibited throughout 30 min following affect ratings as sedentary (0–260 counts/min), light (260–759 counts/min), moderate (760–5,724 counts/min), and vigorous (>5,725 counts/min) for each individual. We calculated both GLMMs with PQL approximation and the more robust glmer analyses with Laplace approximation. For reasons of parsimony, we only report the results for the latter more robust analyses here (see Table 3).

There were significant relationships with affect for sedentary activities, documenting a lower percentage of sedentary periods when both EMA-PAA and EMA-NA increased (for EMA-PAA: $b = -0.009$, $z = -2.40$; for EMA-NA: $b = -0.014$, $z = -2.36$). For the percentage spent in light activities, there were no significant associations with affect; however, for the percentage spent in moderate-intensity activities, there was a significant positive association with EMA-PAA ($b = 0.030$, $z = 2.32$) and a tendency toward a positive association with EMA-NA ($b = 0.033$, $z = 1.91$). These findings suggest that an increase in positive-activated affect was accompanied by an increase in moderate-intensity activities. Although an effect of similar magnitude was found for EMA-NA, this finding should be interpreted with caution since it merely approached significance. Importantly, EMA-PAA also significantly predicted the percentage of time spent in vigorous activities ($b = 0.166$, $z = 2.84$), but there was no relationship with EMA-NA.

Some other associations should be mentioned: First, we found that women spent less time in vigorous activities than men ($b = -0.831$, $z = -2.03$), but they tended to show more periods of light-intensity activity relative to men ($b = 0.145$, $z = 1.74$). Moreover, age was positively related to activities classified as light ($b = 0.010$, $z = 2.75$) and moderate-intensity ($b = 0.010$, $z = 2.70$), but negatively related to vigorous activities ($b = -0.038$, $z = -2.15$). These findings document that older participants spent more time in light and moderate-intensity activities, whereas they did not engage in vigorous activities as much as younger individuals.

**Discussion**

Previous studies have shown that even low-intensity bodily movement predicts alterations in certain affective states (Ekkekakis et al., 2000; Schwerdtfeger et al., 2008). For example, in a previously published study, we were able to show that
Table 3  Generalized Linear Mixed Effects (Poisson) Model of the Percentage of Bodily Movement Exhibited as Sedentary (0–259 counts/min), Light (260–759 counts/min), Moderate (760–5,724 counts/min), and Vigorous Activity (> 5,725 counts/min) on Pre-Affect Bodily Movement, Ecological Momentary Assessed Positive-Activated Affect (EMA-PAA), and Negative Affect (EMA-NA) and Various Demographic Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Sedentary</th>
<th></th>
<th></th>
<th>Light</th>
<th></th>
<th></th>
<th>Moderate</th>
<th></th>
<th></th>
<th>Vigorous</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>b</td>
<td>SE</td>
<td>z</td>
<td>b</td>
<td>SE</td>
<td>z</td>
<td>b</td>
<td>SE</td>
<td>z</td>
<td>b</td>
<td>SE</td>
<td>z</td>
</tr>
<tr>
<td>Intercept</td>
<td>4.277</td>
<td>0.022</td>
<td>192.60**</td>
<td>1.942</td>
<td>0.060</td>
<td>32.34**</td>
<td>2.437</td>
<td>0.065</td>
<td>37.45**</td>
<td>-0.326</td>
<td>0.294</td>
<td>-1.11</td>
</tr>
<tr>
<td>Preaffect movement</td>
<td>-0.095</td>
<td>0.004</td>
<td>-24.09**</td>
<td>-0.067</td>
<td>0.009</td>
<td>7.22**</td>
<td>0.146</td>
<td>0.006</td>
<td>22.76**</td>
<td>0.202</td>
<td>0.01</td>
<td>20.10**</td>
</tr>
<tr>
<td>EMA-PAA</td>
<td>-0.009</td>
<td>0.004</td>
<td>-2.40*</td>
<td>-0.002</td>
<td>0.011</td>
<td>-0.18</td>
<td>0.030</td>
<td>0.013</td>
<td>2.32*</td>
<td>0.166</td>
<td>0.059</td>
<td>2.84**</td>
</tr>
<tr>
<td>EMA-NA</td>
<td>-0.014</td>
<td>0.006</td>
<td>-2.36*</td>
<td>-0.014</td>
<td>0.015</td>
<td>-0.97</td>
<td>0.033</td>
<td>0.017</td>
<td>1.91†</td>
<td>0.060</td>
<td>0.060</td>
<td>0.99</td>
</tr>
<tr>
<td>Sex</td>
<td>-0.025</td>
<td>0.030</td>
<td>-0.81</td>
<td>0.145</td>
<td>0.083</td>
<td>1.74†</td>
<td>0.039</td>
<td>0.090</td>
<td>0.43</td>
<td>-0.831</td>
<td>0.408</td>
<td>-2.03*</td>
</tr>
<tr>
<td>Age</td>
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<td>0.001</td>
<td>-0.86</td>
<td>0.010</td>
<td>0.003</td>
<td>2.75**</td>
<td>0.010</td>
<td>0.004</td>
<td>2.70**</td>
<td>-0.038</td>
<td>0.018</td>
<td>-2.15*</td>
</tr>
<tr>
<td>BMI</td>
<td>-0.002</td>
<td>0.005</td>
<td>-0.34</td>
<td>-0.016</td>
<td>0.014</td>
<td>-1.14</td>
<td>-0.005</td>
<td>0.015</td>
<td>-0.32</td>
<td>0.015</td>
<td>0.068</td>
<td>0.21</td>
</tr>
</tbody>
</table>

Note. Models with Laplace approximation. For each model, EMA-PAA and EMA-NA were allowed to vary randomly between persons. b estimates represent unstandardized partial regression coefficients.
†p < .10, *p < .05, **p < .01.
bodily movement in everyday life was related to subsequent alterations in positive-activated affect, whereas there was no significant association with negative affect. The aim of the current study was to reverse this analysis and to calculate associations between affect and subsequently performed bodily movement in daily life, thereby controlling for preaffect bodily movement. Using a comparatively large data set, we were able to show that EMA-PAA reliably predicted bodily movement alterations in three different time windows (5-min, 15-min, and 30-min). Increases in EMA-PAA were accompanied by increases in bodily movement episodes of varying length. A closer look at effect sizes revealed that an increase in positive-activated affect of 3 points on a scale ranging from 6 to 30 was accompanied by an approximately 13–16% increase in bodily movement.

Of note, in addition to this finding, there were also significant relationships between EMA-NA and bodily movement for the 15-min and 30-min time windows. Generally, increases in EMA-NA predicted higher activity levels. Effect sizes were of similar magnitude as for positive-activated affect (a 3-point increase in negative affect on a scale ranging from 5 to 25 was related to a 14% increase in bodily movement). Hence, this finding appeared to be in contrast to studies suggesting an inverse association between negative affective states and the initiation of physical activity (e.g., Carels et al. 2007; Hamid, 1990; Rhodes & Smith, 2006). However, whereas previous studies focused on physical activity or participation in exercise programs, our aim was to examine psychological concomitants of bodily movement as exhibited in everyday life. We will discuss this relationship later in more detail.

When excluding sedentary periods, the findings did not change substantially. EMA-PAA and EMA-NA increases were accompanied by increases in medium-term bodily movement (15- and 30-min time windows). Effect sizes, however, were somewhat lower as compared with the first set of analyses and did not reach significance for EMA-NA for the 30-min time window. It should be noted that a reduction in variance and a loss of power might have contributed to this shrinkage of associations, especially for the short-term time windows. For example, excluding sedentary periods resulted in a 15% reduction of data for the 30-min time window, a 24% reduction for the 15-min, a 42% reduction for the 5-min, and a 70% reduction for the 1-min time window. Thus, significant effects might not have occurred for the shorter time windows because of a substantial loss of power. Nonetheless, the data show that a 3-point increase in EMA-PAA resulted in a 6–7% increase in bodily movement, and a similar increase in EMA-NA resulted in an 8–12% increase in bodily movement in a time interval 15–30 min after the assessment of affect.

Of particular interest were the analyses of different intensities of bodily movement. We calculated associations for the percentage of time participants spent in sedentary, light, moderate, and vigorous activities, respectively. These analyses revealed that affect was inversely associated with sedentary periods, suggesting that both positive and negative affective states were accompanied by a decrease in sedentary activities. Hence, these findings substantiate our first set of analyses in showing that affective states are related to some kind of bodily movement. Moreover, we found that EMA-PAA was a reliable predictor of moderate and vigorous activity exhibited throughout the day. When participants were feeling lively, active, dynamic, happy, and so forth, they were more likely to engage in moderate and vigorous bodily movement during the next 30 min. Hence, this finding corroborates previous studies that found that positive affective states facilitate physical activity or
participation in exercise programs (e.g., Carels et al., 2007; Hamid, 1990; Herman et al., 2002). To our knowledge, this is the first study to document that positive-activated affect reliably predicts spontaneous moderate- and high-intensity movement as exhibited in daily life. Importantly, this finding is entirely consistent with neurobiological evidence suggesting that brain regions that are involved in positive affect and extraverted behavior (e.g., the ventral tegmental–nucleus accumbens dopamine system and the prefrontal cortex; Depue & Collins, 1999; Dishman et al., 2006) are also closely linked with incentive-related locomotor behavior (i.e., behavioral facilitation including spontaneous exploratory activity behavior). Hence, positive affect and bodily movement may have a common neurobiological foundation, which might explain their interrelationship in daily life.

Of note, our findings also suggest that EMA-NA was significantly positively related to bodily movement and fewer sedentary periods, suggesting that negative affect could facilitate bodily movement in daily life. In our view, there are at least two interpretations available for this effect. First, individuals might have used bodily movement as a mean to improve their affect (mood repair hypothesis; Clark & Isen, 1982). This hypothesis would imply that participants probably engaged in physical activity or exercise to diminish their negative affective state. For example, there is considerable evidence that physical activity or exercise constitutes an efficient strategy to regulate affect (e.g., Augustine & Hemenover, 2009; Larsen & Prizmic, 2004; Thayer, 1987, 2001; Thayer, Newman, & McClain, 1994). Correspondingly, one would expect that negative affect should be positively associated with moderate or vigorous movement episodes. However, there was no robust association for vigorous movement intensity, and the relationship between negative affect and moderate bodily movement merely approached significance. Therefore, we would tentatively suggest that the findings do not support the mood repair hypothesis. Instead, the relationship could reflect emotional expression through bodily movement (i.e., emotional body language; de Gelder, 2006). It has long been recognized that affective states are closely linked to bodily movement and, consequently, emotional body movements play a central role in decoding emotion-relevant information (de Gelder, 2006). For example, Darwin (1872) ascribed certain movement patterns to specific emotions (e.g., the whole body trembles in anger or rage and intends to push or strike violently away). In a similar vein, Ekman and Friesen (1969) argued that bodily movement may help coping with emotions, thus highlighting the behavioral concomitants of affective states. Accordingly, Wallbott (1998) found evidence to suggest that bodily movement is indicative of the quantity of emotion experience, thus suggesting that the dynamic nature of feeling nervous, anxious, or angry could have facilitated bodily movement in our sample to let off steam or act out negative feelings. Of note, this kind of movement might be of lower intensity as compared with more vigorous movement that has been related to health benefits. Our data do not allow a more thorough analysis of these hypotheses. Probably the activity categories used in this study were too coarse to allow a detailed tracking of movement patterns associated with negative affect. In sum, whichever interpretation might be more valid, the findings of this study suggest that negative affective states might be related to some kind of bodily movement. For future studies we would suggest to examine associations between negative affect and bodily movement of different intensity with more scrutiny to help answer the question of how negative affect might contribute to bodily movement in daily life.
Some other findings are worth mentioning. First, we found rather complex associations between age and bodily movement. Whereas age seems to be associated with elevated levels of light- to moderate-intensity activity, we also found negative associations with bodily movement of vigorous intensity. Hence, our findings suggest that various bodily movement types vary with age. Thus, the findings of our study extend the results of previous studies that showed generally lower levels of physical activity with increasing age (e.g., Caspersen, Pereira, & Curran, 2000; Sallis, 2000; Volkers et al., 2002). It would be interesting to examine further whether the exchange of vigorous activity with light to moderate activity in older age is a universal phenomenon. Furthermore, it is unclear whether this shift in activity might be relevant to health outcomes. Hence, we would recommend that future studies on the relationship between age and bodily movement should take movement intensity into account as a possible moderator.

Second, we found that women were less likely to engage in vigorous activities than men. On the contrary, they showed a tendency to exhibit more light-intensity activity. Previous studies had found a general trend for women to be less physically active than men (e.g., Trost et al., 2002; White, Powell, Hogelin, Gentry, & Forman, 1987). Hence, our findings are in accordance with these studies for vigorous physical activity. Nonetheless, the results also suggest that movement intensity should be analyzed in more detail because sex differences in bodily movement seem to depend on the intensity.

Integration of the Findings

Taken together, in accordance with previous studies (Carels et al., 2007; Hamid, 1990), our findings substantiate the assumption that affective states regulate bodily movement and physical activity in everyday life to an appreciable degree. Whereas negative affective states seem to decrease sedentary periods and probably increase low- to moderate-intensity bodily movement, positive-activated affect seems to be reliably related to moderate and vigorous physical activity. Thus, our study suggests that feeling energetic and positive activated seem to foster the initiation of spontaneous bodily movement of higher intensity in daily life. Importantly, recommendations have been proposed to increase daily-life bodily movement or physical activity of moderate intensity rather than to promote vigorous aerobic exercise (e.g., National Institutes of Health, 1996) because changes in behavior are more likely to occur when they are accompanied by positive feelings. The results of this study suggest that interventions targeting affect in daily life could prove useful for reaching this goal. Moreover, it has been suggested that affect has motivational effects, influencing goal attractiveness and optimism about goal attainment (Russell, 2003, 2009; Schwarz & Bohner, 1996). In a positive feeling state, individuals are more confident in their abilities to perform an action and are more likely to find the outcome more attractive (Salovey & Birnbaum, 1989). Hence, for physical activity programs, strategies for enhancing positive-activated affect could constitute a promising addition (see also Carels et al., 2007). It might also be argued that when positive-activated affect is low, bodily movement of moderate intensity could be the treatment of choice to increase affect in daily life. For example, our data suggest that a low-intensity walk increases positive-activated affect by approximately 6–9%, and this amount of increase in affect, in turn, is
related to increases in movement by approximately 12–14%. Thus, once positive-activated affect has increased, it could help in elevating the likelihood for further movement episodes, thus launching a positive feedback loop.

Importantly, the study controlled for bodily movement exhibited for 15 min before the assessment of affect to prevent carry-over effects. Thus, we could rule out the possibility that the relationship between affect and movement was partially influenced by bodily movement effects on affective states. Taken together, the findings lend support for the hypothesis that affect could play a significant role in the initiation of bodily movement. Comparing the results of this study with our previous analysis (Schwerdtfeger et al., 2008), it turns out that there might be circular effects of affect and movement on each other.

Strengths, Limitations, and Future Directions

The study has some notable strengths that should be outlined. Unlike other studies on the relationship between bodily movement/physical activity and affect, the current study applied an ambulatory assessment design with objectively assessed movement, which ensured ecological validity of the data and allowed for the analyses of between- and within-subject correlations of affect and movement. By applying the most recent methodological approaches (multilevel modeling and GLMMs) and recruiting a relatively large sample, we were able to examine the interplay between affect and bodily movement as it unfolds in everyday life. Moreover, the study controlled for preaffect movement levels, thus putting the predictive utility of affect on subsequently performed bodily movement to a much stronger test.

On the other hand, the study also has some limitations that should be mentioned. First, it should be emphasized that daily bodily movement of any kind was recorded (e.g., walking, stair climbing), including many low-intensity activities. Hence, the relationship between affect and physical exercise or participation in sports programs was not the aim of the study (although more vigorous activities or aerobic exercise might have occurred). Therefore, we urge caution in generalizing the results of our study to physical activity programs. However, because we found associations between EMA-PAA and moderate to vigorous bodily movement, we are quite confident that our results are relevant to health promotion programs that aim to facilitate higher-intensity physical activity.

Second, to avoid overburdening participants, we restricted the assessment of affect to 14 items that could be grouped along two factors: EMA-PAA and EMA-NA. Whereas EMA-PAA reflected adjectives that are of both positive valence and high activation, EMA-NA comprised items with negative valence (although all but one item [depression] also reflect high arousal). For future studies, it would be useful to fully counterbalance items across both dimensions (valence and activation) to explore their predictive utility with respect to bodily movement as suggested by the affect circumplex model (Ekkekakis & Petruzzello, 2002; Russell, 2003, 2009).

Third, it should be emphasized that data were collected throughout one day only. Although the majority of our sample rated the recording day as being absolutely or rather typical, there were also participants who rated the day as rather or absolutely atypical. Thus, caution is warranted when generalizing the findings to other days. It could have been that participants behaved differently on the recording day, thus biasing the relationships under study. Consequently, studies
on ambulatory assessed physical activity have recommended recording data for 1 week to estimate habitual (or typical) activity levels. However, despite this criticism, we believe that the relationship between affect and bodily movement might not necessarily depend on the typicality of the day. Our analytic strategy was to calculate within-subject covariation between affect and bodily movement, which should be rather independent of the specificity of certain situations. Nonetheless, future studies should extend data recording to multiple days, although this would require reducing the number of daily affect ratings to ensure high compliance rates.

Fourth, it should be noted that movement was recorded at the foot (left ankle) to record activities such as walking and stair climbing with sufficient sensitivity (e.g., Guinhouya et al., 2005). This location, however, is also sensitive to nervous leg movements and other activities that do not qualify as the target behaviors of this study. In separate test trials we were able to confirm that nervous leg movements (foot tapping) resulted in activity counts of approximately 100–300 counts/min. However, because we replicated our findings for activities exceeding 260 counts/min, and could also find associations with moderate and vigorous bodily movement episodes, we are rather confident that this kind of movement did not bias our results substantially. Nonetheless, it has been suggested that recordings at the hip are more adequate for assessing metabolically relevant whole-body movements (Troost et al., 2005). Thus, future studies should record physical activity at the hip to validate the results of this study. Relatedly, with respect to the affect—movement intensity relationship it should be emphasized that we applied thresholds for identifying sedentary, light, moderate, and vigorous bodily movement episodes as compared with hip placement of the sensor. Thus, it is questionable whether our classification derived from ankle placement of the sensor is valid. According to Guinhouya et al. (2005), activity counts retrieved from hip and ankle placements of the sensor are not directly comparable. In particular, ankle placement of the sensor leads to higher activity counts as compared with hip placement. Accordingly, caution is warranted when interpreting our findings on the relationship between affect and movement of different intensity. Nonetheless, because we are not aware of any other cutoff-values for ankle placement of the sensor we would suggest to interpret the results as a first hint toward affect–movement intensity relationships that have to be validated in future studies.

Another interesting question the current study could not answer refers to the time line of the affect/bodily movement relationship. That is, how long does it take until affect stimulates movement? To date, there is little research that has attempted to answer this question. Previous studies have applied time intervals of several hours (Carels et al., 2007; mood in the morning and exercise during the day) or even multiple days (Hamid, 1990; affect during the previous week predicted participation in an exercise program). We are not aware of any theoretical framework that could guide this research. However, neurobiological studies suggest close links between positive affective states and bodily movement (Depue & Collins, 1999; Dishman et al., 2006), which is compatible with our main finding documenting that affective states and bodily movement are interconnected within several minutes (specifically, 15–30 min). Hence, we would recommend examining short-term or medium-term effects of daily affect with respect to physical activity in more detail.

Finally, it should be mentioned that although there appears to be a causal relationship between affect and bodily movement, there could have been additional
variables that might have influenced both affect and movement in a similar way, thus precluding causal interpretations. For example, it could be argued that feelings of self-efficacy with respect to bodily movement or outcome-expectancy beliefs could have driven the associations under study. Future research should include such measures to examine their relative impact on affect and daily bodily movement. Moreover, more experimental studies are needed to verify a causal pathway between affect and bodily movement of varying intensities.

Notwithstanding these limitations, the current study suggests that positive-activated affect as well as negative affect might facilitate bodily movement in everyday life. The findings could prove useful for designing more effective physical activity intervention programs. Given the possible circular effects of positive-activated affect and bodily movement, it is suggested that engaging in movement improves certain aspects of affect, which, in turn, give rise to the initiation of the next bodily movement episode.

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