Be Active and Become Happy: An Ecological Momentary Assessment of Physical Activity and Mood

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The positive effects of physical activity on mood are well documented in cross-sectional studies. To date there have been only a few studies analyzing within-subject covariance between physical activity and mood in everyday life. This study aims to close this gap using an ambulatory assessment of mood and physical activity. Thirteen participants completed a standardized diary over a 10-week period, resulting in 1,860 measurement points. Valence, energetic arousal, and calmness are the three subscales of mood that were assessed. Participants rated their mood promptly after self-selected activities. A multilevel analysis indicates that the three dimensions of mood were positively affected by episodes of physical activity, such as walking or gardening—valence: $t(12) = 5.6$, $p < .001$; energetic arousal: $t(12) = 2.4$, $p = .033$; calmness: $t(12) = 2.8$, $p = .015$. Moreover, the association is affected by the individual baseline mood level, with the greatest effect seen when mood is depressed.

Keywords: ecological momentary assessment, feelings, activities in everyday life, older adults, within-subject variations, psychological health

Research provides evidence of the benefits of physical activity (PA) for physical and psychological health (e.g., Bucksch & Schlicht, 2006; Raglin, Wilson, & Galper, 2007; Physical Activity Guidelines Advisory Committee, 2008). Those and comparable scientific findings have resulted in a recommendation (e.g., the health-enhancing physical activity [HEPA] recommendation) to be active at a moderate intensity for at least 30 min on all or most days of the week (see also Dishman, Washburn, & Heath, 2004; Haskell et al. 2007).

The majority of scientific research has examined the impact of PA exclusively on negative psychological states such as depression and anxiety, with the majority focused on clinical populations (Wipfli, Rethorst, & Landers, 2008). There are several meta-analyses showing the positive effects of PA and sports on mental health (e.g., Schlicht, 1994). Looking only at the last decade, their results are confirmed by the scientific literature. Two recently published meta-analyses confirm that activities

of low-to-moderate intensity substantially affect the psychological well-being of older, healthy persons as well (Arent, Landers, & Etnier, 2000; Netz, Wu, Becker, & Tenenbaum, 2005). Another meta-analysis examined the effects of acute aerobic exercise on positive affects (Reed & Ones, 2006). The results showed that subjects in the exercise samples had higher positive affect levels when compared with the inactive control groups. In addition, before-and after analyses of changes within subjects in the exercise samples showed increased positive affect levels relative to baseline (see also Puetz, O'Conner, and Dishman, 2006).

Most of the studies integrated into these meta-analyses refer to specific exercise programs or to PA that is planned and structured. They generally do not refer to unstructured daily activities of low-to-moderate intensity (e.g., going for a walk). As such, studies fail to measure the association between PA and mood in everyday life.

Understanding this association and the manner in which PA contributes to enhanced positive feelings and subjective well-being in everyday life may help to answer whether people can manage their mood through their physical activities.

Using ecological momentary assessment (EMA), it is possible to analyze within-subject variations in PA and mood in everyday life. *Ecological momentary assessment* refers to a category of methods that involves the collection of real-time data about current states (e.g., mood, activity) in the natural environment repeatedly over time. Ecological momentary assessment reduces recall bias because data are recorded when events actually occur. The researchers get data that have higher ecological validity in comparison with laboratory methods (Stone, Shiffman, Atienza, & Nebeling, 2007). In addition, multiple assessments of mood from each participant allow for higher power analyses. Ecological momentary assessment provides a strong external validity of within-subject variations in PA and mood.

To date, only a few studies of PA and positive psychological effects have been applied. Hausenblas, Gauvin, Symons Downs, and Duley (2008) analyzed the effects of abstinence from regular exercise on feeling states with EMA. Participants were deprived of their scheduled exercise on three days and maintained their regular exercise routine on three other days. After controlling for diurnal variations, feeling states were significantly better after exercise involvement on exercise days. As with the aforementioned meta-analyses, most of these studies refer to specific activity programs (e.g., Focht, Gauvin, & Rejeski, 2004) or to PA programs that are planned and structured (e.g., Gauvin, Rejeski, & Reboussin, 2000).

However, Schwerdtfeger, Eberhardt, and Chmitorz (2008) analyzed the association of PA in everyday life with positive and negative affects, respectively. The authors conducted an EMA, and multilevel analyses showed that positive affect was significantly and positively associated with preceding PA whereas a negative affect was unrelated to PA.

Compared with the study by Schwerdtfeger et al. (2008), our study analyzes the association between daily activities and mood in healthy people during everyday life; however, we use a different procedure and a different time schedule for the data collection. Thus, we have replicated the research approach but varied the methodological details. We hypothesize that physically active episodes (e.g., going for a walk) are associated with more positive moods compared with episodes of inactivity (e.g., reading a book). We have used EMA and have analyzed intraindividual variations in current mood states depending on different episodes of activity.

Method

Participants and Procedure

The sample was drawn from a larger sample of a cross-sectional study, "Successful Aging and the Effect of Physical Activity." The whole sample included 1,200 randomly selected persons aged 50–60 years living in the southern part of Germany. An institutional review board has approved this study. We obtained written informed consent from each participant. In addition, 16 persons from the original sample had given their written consent to join our study of mood and PA with an EMA approach.

Participants completed a standardized diary over the course of 10 weeks (starting in November 2006 and ending in January 2007). They answered concurrent questions about their physically active episodes and their current state of mood. The participants had to complete the questions directly after their self-selected episodes during their daily routine. Episodes are defined as occurrences with a definite start and a definite end (e.g., going for a walk, reading a book, dining with the family, or gardening). Participants should have selected between one and three episodes per day. All in all, we collected data sets of 70–210 data points per person.

Data from nine females and four males were analyzed. Three people did not fill in the questionnaires correctly and were excluded from the study. These people did not show any significant differences compared with those who completed the questionnaires. Overall we collected 1,860 measurement points belonging to 13 persons.

All participants were between 52 and 59 years old (median = 56.5) and were married. They voluntarily participated in our study. As a token of our appreciation at the end of the study, the participants received a greeting card, a bouquet of flowers at Christmas, and a coupon for books valued at 30 euros.

Measurement Procedures

Momentary Assessment of Self-Selected Activity Episodes. The participants were asked to describe their current activity (e.g., strolling, going for a walk, reading a book, viewing TV, or doing housework). To analyze the data, the two authors and a third expert independently categorized the episodes as physically active or inactive. There was full agreement between the three independent activity coders. We created a dummy-coded indicator variable named *activity* with physically active episodes designated as 1 and physically inactive episodes as 0.

Momentary Assessment of Mood. To measure the basic dimensions of mood (valence, energetic arousal, and calmness) in daily life, the German-language Multidimensional Mood Questionnaire was used (Steyer, Schwenkmezger, Notz, & Eid, 1997). This instrument consists of four unipolar items per subscale. Internal consistency ranged from Cronbach alpha values of 0.73 to 0.89. Participants responded to the statement, "At this moment I feel:" on a 5-point Likert scale using sums of four adjectives for each subscale. Examples include adjectives such as *content* or *happy* for valence, *awake* or *fatigued* for energetic arousal, and *calm* or *relaxed* for calmness. The score of each subscale ranged from 4 (*low value*) to 20 (*high value*).

Analyses

The repeated measurements were best conceptualized as being *nested* within each participant. The number of repeated measures differed across participants, and the repeated measurements could not be considered equidistant across participants. Multilevel analyses (Raudenbush & Bryk, 2002) are an appropriate method to analyze such an EMA data structure. The intraindividual variance (Level 1) is of primary interest here.

In our study, the within-person level (Level 1) was used to estimate the effect of physically active episodes compared with physically inactive episodes on mood states in daily life.

Multilevel analyses allow separate estimates of mood for each episode. They express the intraindividual differences in these estimates as a function of the *activity* variable, as seen in the following formulas:

$$\text{Level 1: } Y_{ti} = \beta_{0i} + \beta_{1i} X_{ti} + r_{ti} \tag{1}$$

$$\text{Level 2: } \beta_{0i} = \gamma_{00} + \mu_{0i} \tag{2}$$

$$\text{Level 2: } \beta_{1i} = \gamma_{10} + \mu_{1i} \tag{3}$$

Level 1 represents the within-subject model and expresses the participants' responses (subscript i) given on the mood subscale (Y_{ti}) in any given diary entry (subscript t). A given response Y_{ti} is defined as the average intercept of that mood subscale across the participants (β_{0i}) plus the average regression slope (β_{1i}). The Level-1 predictor *activity* (X_{ti}) was in its natural metric, with a value of 1 referring to physically active episodes and a value of 0 referring to physically inactive episodes. Even though a predictor in its natural metric includes within- and between-person effects, it allows estimation of exact increases in mood when the person is physically active versus physically inactive. In our case, $X_{ti} = 0$ implies that person i in situation t was inactive. As a result, the intercept β_{0i} is defined as the expected outcome for inactive situations.

A test of the significance of the predictor variable *activity* compares the average feeling state in a physically active episode with that in a physically inactive episode. The α level was set to $p < .05$. The random effect for the Level-1 model is given by r_{ti}. It is assumed to be normally distributed with a mean of 0 and variance of σ^2. We conducted a random-coefficients regression model in which the Level-1 intercept and slope are conceived as varying randomly. Level 2 is unconditional and includes the fixed effects, γ, as the average intercepts and slopes across all persons and the random effects, μ_{0i} and μ_{1i}. These random effects are assumed to be multivariate and normally distributed, both with expected values of 0. We label the variances as τ_{00} and τ_{11}, and the covariances as τ_{01}.

Full maximum likelihood estimations were used for the multilevel analyses. Considering the nested structure of the model, effect size estimation was done with effective degrees of freedom. Formula 4 calculates the $N_{\text{effective}}$ of the models.

$$N_{\text{effective}} = Nn / (1 + (n - 1) \times \rho_I \tag{4}$$

where Nn stands for the number of measurements points, n stands for the average measurement points per person, and ρ_I represents the intraclass coefficient

of the mood subscale of interest. Effective degrees of freedom are analyzed with $N_{\text{effective}}$ minus the number of predictors. We calculate effect size r using t values and effective degrees of freedom.

The models were calculated with the statistical program HLM 6.0 (Raudenbush, Bryk, & Congdon, 2004).

Results

The 13 participants of our study reported 1,860 data points of different activity episodes and corresponding mood states. Of the registered episodes, 28% were related to physically active episodes (e.g., go for a walk, gardening) and 72% were related to inactive episodes (e.g., reading a book, dining). Table 1 presents means and standard deviations of overall mood and the three subscales after physically active and inactive episodes.

First, a model of each mood subscale was tested with a random intercept but without the predictor variable *activity*. Results from these three models revealed that average levels of valence, energetic arousal, and calmness for all participants were $M = 17.4, 15.5$, and 16.4 respectively, representing a daily mood in the neutral-to-high range. The chi-square values associated with the variance component suggest significant between-subject variation for all feeling states (all $p < .001$), allowing the intercepts to vary randomly. The intraclass correlation was $\rho_I = .21$ for valence, $\rho_I = .4$ for energetic arousal, and $\rho_I = .3$ for calmness, indicating that most of the variance of the mood subscale was caused by intraindividual influences.

Next, we entered the predictor variable *activity* into the model. Multilevel analysis was conducted separately for each mood subscale (outcome). Attenuation-corrected correlations between the variable *activity* and each of the three subscales of mood were each negative (valence: –0.79; energetic arousal: –0.21; calmness: –0.40). Thus, for participants whose mood level is higher than the average for all participants, the effect of *activity* is weaker compared with participants whose mood level is lower than the average level for all participants.

Physically active episodes affected all three subscales of mood significantly (see Table 2).

The effect sizes r signified moderate-to-large effects for each subscale as follows: valence ($r = .58$, explained variance = 34%), energetic arousal ($r = .39$, explained variance = 15%), and calmness ($r = .4$, explained variance = 16%).

Table 1   Means and Standard Deviations of the Subscales of Mood and Overall Mood After Physically Active and Inactive Episodes

	Mean (SD) After active episodes (N = 523)	Mean (SD) After inactive episodes (N = 1337)
Overall mood	4.3 (.59)	4.0 (.65)
Valence	4.6 (.50)	4.2 (.67)
Energetic arousal	4.0 (.87)	3.7 (.80)
Calmness	4.3 (.68)	4.0 (.79)

Table 2   Results of the Multilevel Model Analysis Predicting Mood (Valence, Energetic Arousal, Calmness) as a Function of Physical Activity (Dummy Coded). Variance Components of Between-Person and Within-Person Effects Are Presented for Intercepts of the Outcome Variable and Slopes of Physical Activity.

Variance Components Between Persons	Variance Estimate	SE	χ^2 (df)	p Value
Model 1: outcome variable *valence*				
Intercept (μ_{0i})	1.38	1.17	459.8 (12)	< .001
Activity-slope (μ_{1i})	0.24	0.49	27.8 (12)	.006
Level 1 (r_{ti})	4.99	2.23		
Model 2: outcome variable *energetic arousal*				
Intercept (μ_{0i})	4.59	2.14	1280 (12)	< .001
Activity-slope (μ_{1i})	0.75	0.86	47.7 (12)	< .001
Level 1 (r_{ti})	6.42	2.53		
Model 3: outcome variable *calmness*				
Intercept (μ_{0i})	2.95	1.71	878.1 (12)	< .001
Activity-slope (μ_{1i})	0.68	0.82	45.6 (12)	< .001
Level 1 (r_{ti})	6.39	2.52		
Within-Subject Fixed Effects	**Coefficient**	**SE**	**t Value (df)**	**p Value**
Model 1: outcome variable *valence*				
Intercept (μ_{0i})	17.4	0.33	52.71 (12)	< .001
Activity-slope (β_{1i})	1.03	0.18	5.58 (12)	< .001
Model 2: outcome variable *energetic arousal*				
Intercept (β_{0i})	15.52	0.60	25.97 (12)	< .001
Activity-slope (β_{1i})	0.67	0.28	2.41 (12)	.033
Model 3: outcome variable *calmness*				
Intercept (β_{0i})	16.44	0.48	34.2 (12)	< .001
Activity-slope (β_{1i})	0.76	0.27	2.84 (12)	.015

To clarify the magnitude of the effect, we standardized the effects of physically active episodes on the three mood subscales with Formula 5:

$$\text{Standardized effect} = \beta_{1i} \times SD \text{ (activity)} / SD \text{ (mood subscale)} \quad (5)$$

Standard deviation was taken from the mean of the sample of activity and from the mean of the sample of the mood subscales. Standardized effects were 0.83 for valence, 0.47 for energetic arousal, and 0.57 for calmness. Thus, if activity increases by 1 *SD*, valence will increase by 0.83 *SD*, energetic arousal will increase by 0.47 *SD*, and calmness will increase by 0.57 *SD*.

Discussion

Previously, there have only been a few studies analyzing within-subject variations in PA and mood in everyday life. Our study aims to close this gap using an EMA approach.

As expected, within-subject effects indicated that participants feel more content (valence), awake (energetic arousal), and calm (calmness) after being physically active compared with episodes of inactivity. The results replicate those of previous cross-sectional studies (e.g., Reed & Ones, 2006; Puetz et al., 2006), and are in line with the few studies that have analyzed the association between mood and PA using an EMA approach (e.g., Schwerdtfeger et al., 2008; Hausenblas et al., 2008).

Ecological momentary assessment provides a more comprehensive understanding of the association between daily mood experience and PA because the data are assessed in real time when the assumed effect of PA on mood happens. Analyzing the real-time entry of real-world data related to PA and mood was a significant strength of our methodology. Our findings are relevant to understanding the association of mood and PA in everyday life. This understanding may help to explain why older people may be motivated to adopt and maintain physically active lifestyles (Hsiao & Thayer, 1998).

An interesting finding of our study is the negative covariance between the predictor variable *activity* and mood, indicating that the effects of physically active episodes are smaller when mood scores are high. This could be suggestive of a ceiling effect. The higher mood scores are, the less PA affects mood. This finding is consistent with a further momentary assessment study estimating the influence of acute bouts of vigorous intense PA on feelings (Gauvin, Rejeski, & Norris, 1996). Participants completed feeling-state checklists before and after bouts of vigorous activity. According to these results, PA was associated with significant increases in positive engagement, revitalization, and tranquility. Pre- to postactivity differences in mood were moderated by baseline levels of the feeling states. Participants experienced larger positive changes in mood when they felt depressed before starting an active bout of vigorous intense activity.

The ceiling effect shown in our study does not negate the positive association between PA and mood. Rather, it indicates that the effect may be smaller when mood is initially high. The potential of PA may lie in its ability to modify mood when it is at low level and leaving it relatively unchanged when it is already positive. This finding is important because it supports the idea that PA may be a "tool" for mood repair (e.g., Salovey, Brackett, & Mayer, 2004). This is a topic of critical concern to health professionals and public health practitioners who promote well-being and quality of life.

Our pilot study has some methodological limitations, and the results should be considered with appropriate caution. First, although we collected a great number of measurements points, the sample size of our study was very small and the results are limited to persons between 50 and 60 years old.

Second, we did not control for duration of episodes of PA and the exact time of the day at which the episodes took place. Several studies have shown that diurnal variations could have an impact on feelings. That is, positive mood follows predictable patterns across the day. Positive mood seems to be higher in the middle of the day than in the early morning, afternoon, or evening (Gauvin & Spence, 1996).

Third, the type of activity (e.g., reading a book, gardening) was used to assign activity into physically active or inactive episodes. Assignment might be more precise if activities were assessed objectively (e.g., with an accelerometer) and a specific activity cut-off value was used. Fourth, the study does not objectively control for the episodes to which participants rated their mood. That may result in two different biases. First, we do not know whether participants rated their mood directly after the episode or at the end of the day. Participants were allowed to independently choose up to three situations per day. We found an expected distribution of physically active and inactive episodes. Nevertheless, it could be the case that participants mainly chose episodes in which they felt good and happy. This kind of self-selection could have provoked a second bias. Future studies should assess the association between PA and mood interactively while assessing an individual's affect due to a defined activity rate. Lastly, we did not include time-invariant predictors. Because of the small sample size, we were not interested in between-person variance. Nevertheless, there are several studies confirming that mood or subjective well-being is affected by personality or by gender differences (in summary, e.g., Diener, Suh, Lucas, & Smith, 1999). Future studies should analyze whether PA affects mood among females in the same way as among males, for instance. Furthermore, an interesting point of future analysis is whether the amount of overall PA affects the association between mood and PA. In addition, we did not include further time-varying predictors. A review has shown that the context of PA (e.g., transport, leisure) may affect the influence of PA on physical and mental health (Bucksch & Schlicht, 2006). All in all, further studies should analyze which moderators or mediators affect the association between mood and PA in everyday life.

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