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Associations between physical activity and core affects within and across days: a daily diary study

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ABSTRACT

Objective: The objective of the present study was to investigate (a) if daily physical activity at the within-person level is related to four different core affects the same evening, (b) if core affects in the evening predict physical activity the following day, and (c) if physical activity predicts core affects the following day.
Design: A total of 166 university students were asked to complete the affect and physical activity measures once a day (in the evening), for seven days. Bivariate unconditional latent curve model analyses with structured residuals were performed to investigate the relations within days and across days between the core affects and physical activity.
Main outcome measures: Core affects and physical activity.
Results: Physical activity had positive within-day associations with pleasant-activated and pleasant-deactivated core affects and a negative within-day association with unpleasant-deactivated affective responses. There were, however, no statistically significant relations between core affects and physical activity across days.
Conclusion: These results highlight that the measurement interval might be an important factor that influences the association between core affects and physical activity behaviors.

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Core affects; intensive longitudinal design; latent curve model with structured residuals; physical activity

A physically active life is associated with positive effects on both physiological and psychological health (Liao et al., 2015; Wiese et al., 2018). More specifically, studies have shown that regular participation in physical activity is associated with, for example, increased levels of perceived well-being and self-esteem (Poitras et al., 2016). Also, a physically active lifestyle is related to decreased risks of health problems, such as depression, anxiety (Josefsson et al., 2014; Rebar et al., 2015), and obesity (Reiner et al., 2013).

Given the positive health outcomes related to participation in regular physical activity, research has been directed towards investigating factors that might increase the

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likelihood of partaking in physical activities. A majority of the studies have focused on cognitive, social, and environmental predictors of physical activity participation (Williams, 2008). Core affects have also been associated with participation in physical activities, both as a predictor and as an outcome (Ekkekakis et al., 2011; Hyde et al., 2011). Core affects can rapidly change (Knutson et al., 2014), which highlights the need to focus on within-person changes in core affects to capture these rapid changes. The focus of the present study was therefore to investigate the relations between physical activity and core affects within and across days using an intensive longitudinal design.

Russell (2003, p. 148) defined core affect as "…that neurophysiological state consciously accessible as the simplest raw (nonreflective) feelings evident in moods and emotions" and it is similar to what others called activation (Thayer, 1989), affect (Watson & Tellegen, 1985), or mood (Morris, 1989). According to *the circumplex model of affect*, core affects can be classified into different categories (Russell, 1980). Based on a combination of the two continuums, valance (ranges from pleasure to displeasure) and arousal (ranges from activation to deactivation), each core affect can be classified into one of four categories of core affects: (a) pleasant-activated (e.g., happiness), (b) unpleasant-activated (e.g., nervous), (c) pleasant-deactivated (e.g., relaxed), and (d) unpleasant-deactivated (e.g., sadness; Posner et al., 2005).

Core affects are closely related to behaviors, such as physical activity (e.g., Brand & Ekkekakis, 2018). Several theoretical models have been developed to explain how core affects and physical activity are related, such as the dual-mode model and hedonic theory (see Williams, 2008, for a review). In these models, a reciprocal relation between core affects and physical activity is suggested. More specifically, changes in one of the constructs are suggested to influence later changes in the other construct and vice versa. As one example, Williams (2008) suggested that physical activity will influence core affects that, in turn, will influence physical activity adherence.

Several studies have found participation in physical activity to be related to increased levels of pleasant-activated core affects (e.g., Bonham et al., 2018; Hyde et al., 2011; Kanning & Schlicht, 2010; Liao et al., 2015, 2017; Reed & Buck, 2009). Previous studies have, however, reported inconsistent and inconclusive findings for the influence of physical activity on unpleasant core affects (Liao et al., 2015) and the general pattern in previous research is that physical activity has a more pronounced effect on positive affect than negative affect (Liao et al., 2017; Mata et al., 2012; Wichers et al., 2012). Although, recent findings suggest that daily moderate to vigorous psychical activity can decrease the level of depressed and angry affects in the evening in adolescents and young adults (Haas et al., 2017; Langguth et al., 2016).

While several studies have investigated the influence of physical activity on affects, less attention has been given to core affects influence on physical activity behaviors (Reichert et al., 2016). The few studies conducted to date have shown that pleasant core affects positively predicted higher levels of subsequent physical activity (e.g., Carels et al., 2007; Dunton et al., 2009; Liao et al., 2015; Reichert et al., 2016) and that unpleasant core affects predicted lower levels of subsequent physical activity (Liao et al., 2017). These findings highlight that the relation between physical activity and affect is likely bi-directional.

One potential shortcoming in many previous studies, aimed to investigate the relation between physical activity and affects, is that most of them have focused on between-person effects (Kanning et al., 2013). Between-person effects do not necessarily correspond to within-person changes in the construct of interest or within-person relations between two or more constructs (Stadler et al., 2013). In addition, within-person analyses can decrease the risk of erroneous conclusions regarding causal relations between variables (Hamaker et al., 2015). Furthermore, disregarding within-person changes will decrease the ecological validity of the study because the chance that one person's average level of one variable will reflect any true value at any given time point is rather small (Dunton, 2017). By including a within-person perspective into research designs (and data analysis procedures) researchers can examine psychological processes that most likely occurs within individuals (Dunton, 2017; Stenling et al., 2017). Using an intensive longitudinal design is one suitable approach to investigate the relations between physical activity and core affects at the within-person level (Stadler et al., 2013). When applying an intensive longitudinal design, the researcher collects data repeatedly over a short period of time (e.g., on a daily basis for a week), which makes it possible to examine rapid fluctuations in the processes of interest (Langguth et al., 2016).

Given these advantages of applying a within-person perspective, several studies have during the last decade used an intensive longitudinal design (and within-person analyses) to investigate the relation between physical activity and core affects (for a summary of studies see, for example, Liao et al., 2015). Dunton et al. (2014), for example, found that core affects and moderate-to-vigorous physical activity were reciprocally related. One limitation in many of the previous studies applying a within-person perspective, however, is that different models have been used to test different effects (both autoregressive and bidirectional). The common practice has been to test the bidirectional effects separately in a multilevel set-up (e.g., Dunton et al., 2014; Liao et al., 2017). To increase the likelihood of making reliable conclusions" it is necessary to include all relevant variables into your model" (Kuiper & Ryan, 2018, p. 818). One study, using a cross-lagged panel model (including both autoregressive and cross-lagged effects) were conducted to test potential reciprocal effects between incidental affect and exercise behaviors within days (Emerson et al., 2018). In that study a multilevel set-up were used to separate the within- and between-person effects. The results showed that positive incidental affects were related to an increased likelihood of exercising later that day. Also, there was a statistically significant effect of exercise on positive incidental affect. In this study, however, only data on positive affect was collected.

To overcome the potential limitation with not including cross-lagged paths within the statistical models and answer the call for more research on the bidirectional and within-person relations between affects and physical activity, we designed our study to be able to capture such relations using within-person analyses where both autoregressive and cross-lagged effects are specified in the same model. In addition, we included all four categories of core affects as suggested in the circumplex model of affect.

Based on these theoretical and methodological considerations the objective of the present study was to investigate (a) if daily physical activity at the within-person level is related to the four different core affects the same evening, (b) if core affects in the evening predict physical activity the following day, and (c) if physical activity predicts core affects the following day. Based on the previous studies we hypothesize that: (H1) there is a positive association between daily physical activity and pleasant core affects, and a negative association between daily physical activity and unpleasant core affects; (H2) there is a positive bi-directional relation between pleasant core affects and physical activity, and (H3) there is a negative bi-directional relation between unpleasant core affects and physical activity.

Method

Design and procedure

Participants were students recruited at three universities in Sweden. During class they were informed about the objectives, procedure, and ethical concerns related to the study. After class, the students that agreed to take part in the study were asked to provide their e-mail address to the researchers. All students that agreed to take part in the study were contacted by e-mail, containing information about the study (objectives, procedure, and ethical concerns), a personal self-elected ID-number, as well as a link to the web-based questionnaire. The first time the students opened the questionnaire they provided informed consent before commencing the study. We used an intensive longitudinal design where participants were asked to provide data about core affects and physical activity once a day (i.e., in the evening) for seven days. Data was collected using a web-based survey programmed in Qualtrics Survey Software.

Participants

We used the Preacher and Coffman (2006) computer software to estimate the required minimum sample size to reach a statistical power of .80. Using the recommended values for RMSEA to test close fit (MacCallum et al., 1996) the minimum sample size was 138. Participants were 166 male ($n = 51$) and female ($n = 112$; 3 students did not report gender) university students, between 18 and 41 years of age ($M = 25.12$, $SD = 5.19$). The students were recruited from either sport or health science programs, psychology programs, or police education programs.

Materials and measures

Leisure time exercise questionnaire

The Leisure Time Exercise Questionnaire (LTEQ) was used to measure self-reported physical activity levels (Godin & Shephard, 1985). The LTEQ contains three questions where the participants are asked to indicate how many times, for at least 10 minutes, they were engaged in strenuous, moderate, and mild physical activity. In the present study we followed the recommendation from Godin (2011) that “consequently, a final score in units obtained with activities in the intensity categories of strenuous and moderate activities, would most likely be better than the same score obtained with a combination of activities in all three intensity categories” (p. 19). To focus on moderate-vigorous intensities is also in line with recent public health recommendations (Strath et al., 2013). In the current study we, therefore, decided to use the two categories (a) strenuous, and (b) moderate physical activity during each day. Following the recommendation for the LTEQ a metabolic equivalent of exercise (MET) was calculated by adding the weighted sums for the minutes of physical activity reported for each of the physical activity levels: (9*minutes of strenuous physical activity) + (5* minutes of moderate physical activity).

Daily core affects

Daily core affects were measured by 12 items (three items for each of the four categories) representing the four categories in the circumplex model. The 12 items used were taken from the list of 20 items used by Hyde et al. (2011), based on the four quadrants of core affect (Kuppens, et al., 2007). For each of the 12 items the participants were asked to answer the question "Looking back on everything that happened to you today and considering the day as a whole, please answer each statement below. Today I felt…". Participants responded to the items on a VAS-scale ranging between 0 (did not feel so at all) to 100 (felt exactly so). Pleasant-activated responses were measured by the items excited, happy, and alert (Cronbach's $\alpha = .78$, day to day range between .70 to .83). Pleasant-deactivated responses were measured by the items calm, relaxed, and satisfied ($\alpha = .79$, day to day range .68 to .79). Unpleasant-activated responses were measured by the items nervous, upset, and stressed ($\alpha = .74$, day to day range .62 to .79). Unpleasant-deactivated responses were measured by the items sluggish, sad, and depressed ($\alpha = .78$, day to day range .65 to .76). Mean values were then computed for each of the four categories and manifest scale scores were used in the main analysis.

Data preparation and statistical analysis

All analyses were performed in Mplus version 7.4, using the robust maximum likelihood estimator. We considered the missing data as missing at random (MAR) and used the full information maximum likelihood (FIML) estimation to handle the missing data. For all analyses $p < .05$ were used as cut-off for statistical significance. Prior to the main analysis, intra-class correlations (ICC) were calculated for all variables (i.e., core affects and physical activity). The ICC provide information about the proportion of variance that is present at between-person level.

In relation to the study aims four separate bivariate unconditional latent curve models with structured residuals (LCM-SR; Curran et al., 2014, see Figure 1) were estimated, one for each core affect. The LCM-SR have recently been suggested as a viable statistical model that incorporates both between- and within-person relations (e.g., between physical activity and core affects) and, at the same time, controls for the autoregressive effects within each construct. In comparison to the more commonly used multilevel modeling approach, the LCM-SR is better suited to specify cross-lagged relationships at the within-person level. In the bivariate LCM-SR the univariate LCM-SR for physical activity was combined with the univariate LCM-SR for each of the four core affects (see Curran et al., 2014, for more information about LCM-SR). For all

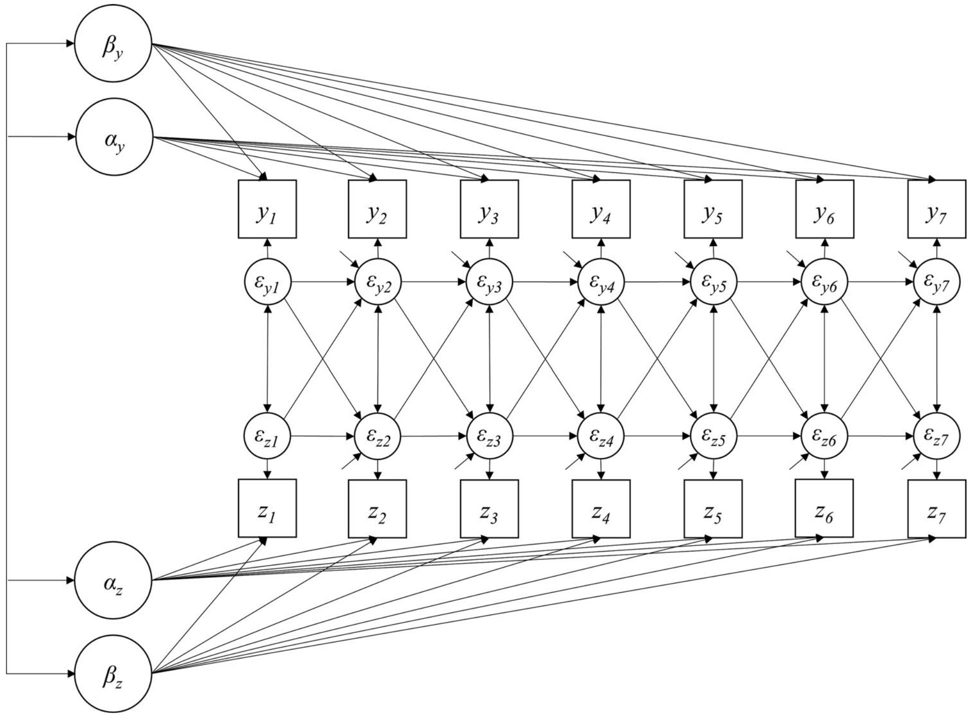

Figure 1. Bivariate unconditional latent curve model with structured residuals (LCM-SR) for seven repeated measures.

constructs we applied random intercept models with an autoregressive component among the residuals. For each bivariate unconditional LCM-SR four nested models were tested. In model A the time-specific residuals were allowed to covary between physical activity and affective responses, representing within-day relations. These covariances were set to be equal over time. In addition, autoregressive paths for the two constructs were specified. In model B the residuals of core affects were regressed on the residuals of physical activity. In model C we removed the regressions specified in model B and regressed the residuals of physical activity on the residuals of core affect. In model D we estimated a full bidirectional model with cross-lagged paths between the residuals in both directions. The nested models were compared using the Satorra-Bentler scaled Chi-square test (Satorra & Bentler, 2010). A statistically significant Chi-square difference test (at $\alpha = .05$) indicated that the subsequent model fitted the data better than the previous model (e.g., model B provided a better fit to the data compared to model A). The goodness-of-fit indices used to evaluate the model in this study were: comparative fit index (CFI), the root mean square error of approximation (RMSEA) with 90% confidence interval (CI), and the standardized root mean squared residual (SRMR). Traditional cut-off criteria (CFI > 0.90, SRMR and RMSEA < 0.08) were used to indicate acceptable fit (Marsh, 2007).

We performed sensitivity analyses using the same procedure as described above to examine the influence of attrition on the results. In the sensitivity analyses only participants who had data over three consecutive days (or more) were included ($n = 106$). The reasons for setting the cut-off for was subjective and based our intention to: (a) have as many participants included as possible and, (b) to have a sequence where bi-directional paths are present in the data. Also, to explore potential patterns of missing data we conducted independent t-test to investigate differences in the number of missing data points between males and females. We also conducted correlations to test the relationships between the number of data points and physical activity measured at baseline.

Results

A total of 2380 data points had no values, and were therefore treated as missing data (41%), leaving 3430 data points for the analyses. The results from the sensitivity analyses were almost identical to the results when using the full sample. We therefore decided to present the results from the analyses using the full sample. The results from the additional sensitivity analyses showed that there was no statistically significant in the number of missing data points between females and males (t = (1,161) 1.05, p = .29, d = 0.18). There were no statistically significant correlation between physical activity, measured at baseline, and the number of missing data points (r = .13, p = .12).

Descriptive statistics are presented in Table 1. On average, the participants experienced higher levels of pleasant core affects in comparison to unpleasant core affects. The ICC estimates for the core affects and physical activity ranged from .25 to .42, indicating substantial within-person variance in these variables.

Physical activity and pleasant-activated core affects

Following the model-building strategy described in the method section, model A (containing only autoregressive paths for the two constructs) was considered to be the optimally fitting model (for test statistics see Table 2). This model showed good fit to the data, χ^2 = 114.71, p = .09, CFI = .94, RMSEA = .03 (90% CI = [.00, .06]), SRMR = .09. The variances for physical activity (.42, p = .001) and pleasant-activated core affects (.22, $p < .001$) were statistically significant, indicating heterogeneity in both variables between the participants. There was no statistically significant relation between the two intercepts (r = .08, p = .08). More specifically, there was, at the between-person level, no statistically significant relationship between the variables at the first measurement point (i.e., baseline).

There was a statistically significant autoregressive effect for pleasant-activated core affects (β = .16, 95% CI = [.01, .29], p = .047), but not for physical activity (β = −.03, 95% CI = [−.18, .10], p = .72). More specifically, the level of pleasant-activated core affects one day was positively related to the level of pleasant-activated core affects the following day. For physical activity there was no statistically significant relation between physical activity in one day and physical activity the following day. The cross-sectional within-person correlation between physical activity and pleasant-activated responses was statistically significant (r = .18, 95% CI = [.08, .28], $p < .001$), indicating a positive within-day relation between physical activity and pleasant-activated core affects.

Table 1. Descriptive statistics and correlational estimates for the relation between the included variables.

Variable	M	SD	ICC	1	2	3	4	5
1. DPA	435.76	347.56	.39	–	.35*	.22*	−.18	−.41*
2. PACA	58.44	13.90	.25	.27*	–	.82*	−.51*	−.73*
3. PDCA	57.67	15.74	.34	.13*	.54*	–	−.81*	−.60*
4. UCA	30.48	17.27	.42	−.01	−.32*	−.62*	–	.72*
5. UDCA	30.18	16.78	.36	−.28*	−.74*	−.51*	.41*	–

Note: DPA = Daily Physical Activity; PACA = Pleasant Activated core affects; PDCA = Pleasant Deactivated Core Affects; UACA = Unpleasant Activated core affects; UDCA = Unpleasant Deactivated Core Affects; ICC = Intra-class correlation; Between-person correlations is presented above the diagonal; Within-person correlations is presented below the diagonal.
*= $p < .05$.

Physical activity and pleasant-deactivated core affects

The Chi-square difference tests showed that the baseline model (model A) was considered to be the optimally fitting model (for test statistics see Table 2). This model showed adequate fit to the data, χ^2 = 121.00, p = .04, CFI = .93, RMSEA = .040 (90% CI = [.008, .060]), SRMR = .10. The variances for physical activity (.42, p = .001) and pleasant-deactivated core affects (.27, p <.001) were statistically significant, indicating heterogeneity in both variables between the participants. There was no statistically significant relation between the two intercepts (r = .05, p = .33). More specifically, there was, at the between-person level, no statistically significant relationship between the variables at the first measurement point (i.e., baseline).

There was a statistically significant autoregressive effect for pleasant-deactivated core affects (β = .27, 95% CI = [.12, .42], p < .001), but not for physical activity (β = −.04, 95% CI = [−.19, .12], p = .66). More specifically, the level of pleasant-deactivated core affects one day was positively related to the level of pleasant-deactivated core affects the following day. For physical activity there was no statistically significant relation between physical activity in one day and physical activity the following day. The cross-sectional within-person correlation between physical activity and pleasant-deactivated core affects was statistically significant (r = .09, 95% CI = [.02, .16], p =.012), indicating a positive within-day relation between physical activity and pleasant-deactivated core affects.

Physical activity and unpleasant-activated core affects

The Chi-square difference tests showed that the baseline model (model A) was considered to be the optimally fitting model (for test statistics see Table 2). This model showed good fit to the data, χ^2 = 103.72, p = .28, CFI = .98, RMSEA = .022 (90% CI = [.000, .048]), SRMR = .08. The variances for physical activity (.42, p = .001) and unpleasant-activated core affects (.31, p <.001) were statistically significant, indicating heterogeneity in the measures between participants. There was no statistically significant relation between the two intercepts (r = −.07, 95% CI = [−.16, .02], p = .14). More specifically, there was, at the between-person level, no statistically significant relationship between the variables at the first measurement point (i.e., baseline).

There was a statistically significant autoregressive effect for unpleasant-activated core affects (β = .32, 95% CI = [.17, .46], p < .001), but not for physical activity (β =

Table 2. Model fit indices for the nested models.

	Model A	Model B	Model C	Model D
PACA				
BIC	3645.15	3648.12	3649.29	3651.63
S-BIC	3572.34	2572.14	3573.30	3572.49
Chi2 (*p*-value)	114.71 (.09)	112.25 (.11)	114.24 (.09)	111.13 (.11)
CFI	.94	.94	.94	.94
RMSEA [90% CI]	.03 [.00-.06]	.03 [.00-.06]	.04 [.00-.06]	.03 [.00-.06]
SRMR	.09	.09	.09	.09
PDCA				
BIC	3620.19	3624.82	3624.76	3629-08
S-BIC	3547.38	3548.84	3548.78	3549.93
Chi2 (*p*-value)	121.00 (.04)	120.58 (.04)	120.75 (.04)	120.04 (.04)
CFI	.93	.93	.93	.92
RMSEA [90% CI]	.04 [.01-.06]	.04 [.01-.06]	.04 [.01-.06]	.04 [.01-.06]
SRMR	.10	.10	.10	.10
UACA				
BIC	3600.14	3605.08	3604.85	3609.57
S-BIC	3527.32	3529.09	3528.86	3530.42
Chi2 (*p*-value)	103.72 (.28)	103.62 (.29)	103.26 (.26)	102.97 (.25)
CFI	.98	.98	.98	.98
RMSEA [90% CI]	.02 [.00-.05]	.02 [.00-.05]	.02 [.00-.05]	.02 [.00-.05]
SRMR	.08	.08	.08	.08
UDCA				
BIC	3606.09	3610.35	3609.11	3612.78
S-BIC	3533.27	3534.36	3533.12	3533.63
Chi2 (*p*-value)	118.58 (.06)	117.55 (.06)	116.27 (.07)	114.63 (.07)
CFI	.95	.95	.95	.95
RMSEA [90% CI]	.04 [.00-.06]	.04 [.00-.06]	.04 [.00-.06]	.04 [.00-.06]
SRMR	.09	.09	.09	.09

Notes: PACA = Pleasant activated core affects; PDCA = Pleasant deactivated core affects; UACA = Unpleasant activated core affects UDCA = Unpleasant deactivated responses; BIC = Bayesian information criterion; S-BIC Sample-size adjusted Bayesian information criterion; CFI = Comparative fit index; RMSEA = Root mean square error of approximation; SRMR = Standardized root mean squared residual; CI = Confidence interval.

−.04, 95% CI = [−.19, .10], p = .58). More specifically, the level of unpleasant-activated core affects one day was positively related to the level of unpleasant-activated core affects the following day. For physical activity there was no statistically significant relation between physical activity in one day and physical activity the following day. The cross-sectional within-person correlation between physical activity and unpleasant-activated core affects was weak and not statistically significant (r = .01, 95% CI = [−.05, .07], p =.73).

Physical activity and unpleasant-deactivated core affects

The Chi-square difference tests showed that the baseline model (model A) was considered to be the optimally fitting model (for test statistics see Table 2). This model showed adequate fit to the data, $\chi^2 = 118.58$, $p = .06$, CFI = .95, RMSEA = .038 (90% CI = [.000, .059]), SRMR = .09. The variances for physical activity (.42, p = .001) and unpleasant-deactivated core affects (.34, $p < .001$) were statistically significant, indicating heterogeneity in both variables between the participants. There was a negative statistically significant relation between the two intercepts (r = −.10, 95% CI = [−.19, −.02], p = .02) indicating that, at the between-person level, high levels of unpleasant-deactivated responses were associated with low levels of physical activity at the first measurement point (i.e., baseline).

There was a statistically significant autoregressive effect for unpleasant-deactivated core affects (β = .16, 95% CI = [.01, .31], p = .049), but not for physical activity (β = −.02, 95% CI = [−.16, .12], p = .81). More specifically, the level of unpleasant-deactivated core affects one day was positively related to the level of unpleasant-deactivated core affects the following day. For physical activity there was no statistically significant relation between physical activity in one day and physical activity the following day. The cross-sectional within-person correlation between physical activity and unpleasant-deactivated core affects was statistically significant (r = −.15, 95% CI = [−.31, .05], $p < .001$), indicating a negative within-day relation between physical activity and unpleasant-deactivated core affects.

Discussion

The objective of the present study was to investigate (a) if daily physical activity at the within-person level is related to four different core affects the same evening, (b) if core affects in the evening predict physical activity the following day, and (c) if physical activity predicts core affects the following day. The results showed partly support for the first (a) hypothesis. More specifically, higher level of physical activity was related to higher levels of pleasant core affects (both activated and deactivated) within days. Higher level of physical activity was also related to lower levels of negative-deactivated core affects within days. The autoregressive day-to-day paths were statistically significant for all affective responses, but not for physical activity. The model testing procedure showed that the inclusion of day-to-day cross-lagged effects did not improve the model fit, indicating marginal magnitude of these effects. Neither the second (b) nor the third (c) hypotheses were therefore supported. These results show that there were no day-to-day effects of physical activity on core affects or vice versa, only relations within days.

The positive within-person relation between daily physical activity and pleasant-activated responses is in line with previous research (e.g., Dunton et al., 2014; Hyde et al., 2011; Kanning et al., 2015). A potential explanation for this relation is changes in neurobiological processes due to physical activity. Physical activity is, for example, associated with increased cerebral blood flow as well as changes in dopamine, serotonin, and norepinephrine levels (Matta Mello Portugal et al., 2013). These changes are, in turn, related to increased levels of pleasant-activated core affects (Hyde et al., 2011).

The negative association between physical activity and unpleasant-deactivated core affects, at the within- and between-person level, are also in line with previous findings (e.g., Langguth et al., 2016). Other studies have, however, found mixed support for the relationship between physical activity and unpleasant-deactivated core effects (Liao et al., 2015, 2017). This finding might, however, be of clinical relevance because unpleasant-deactivated responses are closely related to depressive symptoms (Wichers et al., 2012). One potential explanation to this finding is that physical activity can inhibit a dysfunctional regulation of the Hypothalamic–Pituitary–Adrenal (HPA) axis (Morgan et al., 2015). Such changes in the HPA axis activity are related to positive outcomes, such as lower cortisol levels, improved immune responses (Matta Mello

Portugal et al., 2013) These positive outcomes may, in turn, decrease the level of depressive symptoms (Helmich et al., 2010). The HPA axis responses to exercise are, however, modulated by intensity and duration (Duclos et al., 2007). As one example, if the exercise is performed with intensity above approximately 60% of VO_2 max the cortisol response from the HPA axis will be activated (Luger et al., 1987).

Concerning day-to-day within-person relations, only the autoregressive effects for the core affects were statistically significant. Because core affects to some extent are related to personality traits, such as neuroticism and extraversion, it is likely that some of the variability in these variables is stable over time (Eid & Diener, 1999; Moskowitz & Zuroff, 2005). The findings of weak day-to-day associations between physical activity and core affects, manifested in the non-improved model fit indices and non-statistically significant effects in the models with cross-lagged paths, shows that the time between the measures might be of importance. More specifically, most of previous studies that have reported a relation between positive core affects and physical activity (Liao et al., 2015) have investigated the relation over very short periods of time (e.g., within minutes or a few hours), which likely increases the magnitude of the relation (Dunton et al., 2009, 2014). These results highlight the importance of considering the time between measurement points when investigating the cross-lagged effects between core affects and physical activity. How different measurement intervals will influence the magnitude of the relation between core affects and physical activity is important to examine in future research.

The results also showed a lack of day-to-day effects of core affects on physical activity. These results are in line with the results from a systematic review concluding that post-exercise core affects had marginal effects on future physical activity (Rhodes & Kates, 2015). One potential explanation is that the effect of post-behavior (e.g., exercise) core affects on health behaviors might be mediated by reflective motivation (e.g., behavioral intention, goal) as well as affectively charged motivation (e.g., craving, desire, fear; Williams & Evans, 2014). Whether core affects have an effect on physical activity behavior via motivational factors would be an interesting area to explore in future research (Ekkekakis et al., 2005).

Based on the results future studies are recommended to investigate how different measurement intervals influence the magnitude of the relation between core affects and physical activity. In addition, studies that investigate motivational variables as potential mediators between core affects and physical activity behaviors, might generate practical implications and strategies for optimal intensity levels and exercise structure based on hedonic experiences during activity (see also Ekkekakis & Dafermos, 2012)

Limitations

First, the study only measured core affects once a day. Because core affects can rapidly change this might be a limitation in the current study. Second, in the current study a composite score was used as the indicator of physical activity. This might be a limitation because previous research have suggested that different physical activity levels (i.e., high, moderate, low) have different influences on core affects (Ekkekakis et al., 2005). Because previous studies have shown that both the validity and reliability of measuring low-intensity activity with self-report measures is rather poor (Shephard, 2003) we decided to only focus on high and moderate-intensity activity. Third, self-reports were used to measure physical activity. Using self-reported physical activity indicators is considered as a limitation because previous research has shown weak relations between subjective and objective monitoring of physical activity (Celis-Morales et al., 2012). This divergence can, for example, be attributed to social desirability (Brenner & DeLamater, 2014) or recall bias (Shephard, 2003). More specifically, because physical activity was reported in the end of the day a person's core affects at that occasion might influence how the number of minutes of physical activity that day are recalled and reported. The level of physical activity should, therefore, be interpreted with caution, although the participants were asked to indicate their level of physical activity on a daily basis to decrease the risk for recall bias.

Conclusions

Levels of physical activity seem to have a positive within-day association with pleasant core affects and a negative within-day association with unpleasant-deactivated core affects. There were, however, no statistically significant relations between core affects and physical activity across days. More specifically, the result show that the strength of the relationships between core affects and physical activity are decreasing when the time between measures are increasing. Continuous physical activity participation is, therefore, one good way to increase well-being over time. To express it differently, "to exercise each day keeps the unpleasant emotions away".

Ethics approval and consent to participate

The American Psychological Associations ethical standards were followed in the conduct of the study. Written informed consent was obtained from all participants prior to the first data collection.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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