An experience sampling study of physical activity and positive affect: investigating the role of situational motivation and perceived intensity across time

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Abstract

The nature of the association between physical activity and positive affect is complex, prompting experts to recommend continued examination of moderating variables. The main purpose of this 2-week field study was to examine the influence of situational motivational regulations from self-determination theory (SDT) on changes in positive affect from pre- to post- to 3-hours post-physical activity. Another purpose was to clarify the relationship between physical activity intensity [*i.e.*, Ratings of Perceived Exertion (RPE)] and positive affect at the stated time points. This study employed an experience sampling design using electronic questionnaires. Sixty-six healthy and active, multiple-role women provided recurrent assessments of their physical activity, situational motivation, and positive affect in their everyday lives over a 14-day period. Specifically, measures were obtained at the three time points of interest (*i.e.*, pre-, post-, 3-hours post-physical activity). The data were analyzed using multilevel modeling. Results showed that intrinsic motivation was related to post-physical activity positive affect while the influence of identified regulation appeared 3-hours post-physical activity. In addition, RPE, which was significantly predicted by levels of introjection, was more strongly associated with an increase in positive affect post-physical activity than three hours later. The theoretical implications of these findings *vis-à vis* SDT, namely in regards to a viable motivational sequence predicting the influence of physical activity on affective states, are discussed. The findings regarding the differential influences of RPE and motivational regulations carries applications for facilitating women's well-being.

Introduction

Physical activity has been identified as a key contributor to people's quality of life.[1] [Physical activity is defined as movement of the body that results in energy expenditure; this can be freely chosen and/or integrated into one's routine. Exercise is similarly defined but is more restrictive in that it refers to movement that is planned, structured and repetitive with an objective of maintaining/improving fitness.[2] Although many studies in the domain of interest have been carried out referring to structured exercise, we will employ the more global physical activity term for our purposes and data in order to capture a broader spectrum of physical activities]. More specifically, physical activity can benefit individuals by improving their mental health and well-being.[3,4] Affective states are a defining attribute of well-being; and higher positive affect levels accumulated over time have been linked to physical and psychological health.[5] Much research has revealed a significant association between physical activity and affect, particularly in active individuals.[6,7] Women have also been found to accrue unique benefits from physical activity in terms of reducing the negative affect symptoms of anxiety and depression and improving levels of positive affect.[8,9]

In this literature, experimental designs and cross sectional approaches have been prevalent.[10] For instance, in a repeated-measures laboratory study with female runners, Guérin and Fortier found an increase in positive affect after 30-minutes of running versus a control task.[11] However, it is difficult to examine physical activity and affect fluctuations over time when participants are confined to a laboratory and/or have to recall their affective states over several hours, days, or weeks. The *Experience Sampling Method* (ESM),[12] or *Ecological Momentary Assessment*, can alleviate these methodological difficulties.[13,14] In short, the ESM allows for standardized examination of participants' thoughts, feelings and behaviours in their daily lives. In particular, ESM is ideally suited to collect data on daily physical activity and affect taking into account participants' naturalistic contexts.[15-17]

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Physical activity and positive affect: overview

Researchers have identified a relationship between physical activity and positive affect in the acute period surrounding a physical activity session,[18,19] as well as more generally in terms of overall positive affect.[20,21] With respect to short-term associations specifically, several studies have revealed significant increases in positive affect post-physical activity.[22,23] However, opposite findings have also been shown, revealing some inconsistency in this relationship.[24] To our knowledge, less is known regarding the lasting effects on affective states in the hours after physical activity. Some studies have observed reductions in anxiety 30 to 90 minute post- and up to three hours post- exercise.[25,26] In terms of positive affect, Cox *et al*.[27] found no effect of time following exercise in a female sample, while another study found an increase that was maintained three hours later.[28] Reed and Ones remarked that improvements in positive affect post-exercise can vary from one to several hours later,[19] but they also conclude that more research is needed as the findings are less than conclusive. Therefore, the preliminary purpose of this study will be to examine the change in positive affect from pre- to post- to 3-hours post-physical activity using experience sampling data over a 2-week period.

Physical activity and positive affect: moderators

It is apparent from the literature that several factors can dictate how strongly the effects of physical activity may occur initially and how long they might last.[19] Indeed experts stress that the associations between physical activity and affect are complex and they continue to call for more research examining the underlying mechanisms.[29,30] The intensity of physical activity is one moderator that has received considerable attention in this area.

Intensity and perceived exertion

Studies have revealed that moderate intensity physical activity may provide significant benefits in positive affect.[19,20] However, there is notable variability in this literature. For instance, Rendi and colleagues found that affective states following acute exercise were not associated with Ratings of Perceived Exertion (RPE),[31] a subjective indicator of intensity that correlates well with objective measures.[32] Conversely, Cox *et al.*[27] found that in middle-aged women, higher intensity exercise resulted in greater positive affective changes with sustained effects up to 90 minutes post-exercise. Other experts argue less for a specific threshold but rather that the intensity be preferred/self-selected.[33] Even with an emphasis on self-paced activity, evidence of complicated mechanisms underlying the influence of physical activity intensity warrants that this predictor not be ignored, particularly in the immediate post-physical activity period. Thus, another objective of this study, and one of the first ESM studies to do so, will be to examine and clarify the association between RPE and levels of positive affect post-physical activity as well those sustained 3-hours post-physical activity using measures from multiple physical activity sessions over time.

Recently, experts have also called for more research examining psychosocial factors, in addition to neurobiological factors (*i.e.*, indirectly via intensity-related influences), in explaining the physical activity-affect relationship.[6] Indeed, more knowledge is needed regarding psychological, theory-based variables that may influence this association.[19,34] Self-determined motivation is one construct that deserves greater attention having shown promise in studies of physical activity behavior and well-being.[35,36]

Self-determined motivation

Self-Determination Theory (SDT) is a well-supported theory for understanding motivation-related constructs in the context of physical activity as well as for predicting people's well-being.[37] It is assumed within SDT that growth and integration are two innate tendencies that are shared by all individuals, and that when properly nurtured, can facilitate functional, healthy behaviors and wellness. Central to SDT is the process of internalization, whereby motives to engage in a behavior become increasingly integrated into one's sense of self.[38] This process is explained by the founders of SDT as a *continuum* of motivational regulations that become increasingly more self-determined (*i.e.*, characterized by volition, choice and autonomy), leading to progressively more adaptive behavioral and psychological consequences.[37,39,40]

The spectrum of motivation runs from amotivation, representing the absence of any intention to engage in the behavior, to intrinsic motivation (IM) characterized by inherent satisfaction, fun, and enjoyment of the activity for its own sake.[38] In between lies: external regulation (EX), arising from a desire to achieve an external reward or to avoid punishment, followed by introjected regulation (IJ), whereby one is motivated by personal feelings of shame, guilt, or a conditional sense of self-worth. With increased internalization, one considers the activity as important and assigns it personal importance [identified regulation; (ID)] and lastly on the continuum is integrated regulation.[38] Theoretically, IM and ID are assumed to have positive relationships with indicators of well-being (*i.e.,* positive affect) while IJ and EX should be tied to lower enjoyment (*i.e.*, IM) and thus more negative consequences.[40]

Research has supported that greater self-determined motivation for physical activity is associated with more vitality, higher levels general positive affect, and elevated positive affect following structured exercise.[21,22,41] Both IM and ID regulations have shown positive correlations with daily measures of exercise-related affect.[42] In a similar study, Lepage and Crowther found that health and fitness motivation,[43] which can be theoretically linked with ID regulation, had a significant effect on positive affect following physical activity. These findings complement empirical findings regarding the importance of ID regulation in explaining persistence in strenuous physical activity, a behavior that may not always be inherently enjoyable.[44-46]

Interestingly, IJ regulation, which tends to be higher in women, has also been associated with engaging in physical activity.[44,47] However, Pelletier and colleagues found that IJ predicted short-term participation in physical activity but not persistence over time.[48] Moreover, as stated in a recent empirical review in the exercise domain, high levels of IJ might also come at a cost to one's psychological health.[35] Some studies, such as Kwan *et al.*,[49] have found no links between IJ and exercise-related affect. However, several studies have linked IJ regulation for physical activity with lower scores on indicators of well-being like vitality and life satisfaction.[36,50] Indeed researchers hold particular reservations about the influence of IJ on well-being over time.[51,52] Lastly, associations between EX regulation and indicators of well-being (*e.g.*, affect) have been non-existent or negative.[53,54]

To our knowledge, little work has been done to examine the influence of the motivational regulations from SDT on positive affect in the time frame surrounding physical activity.[11,51] Moreover, aligned studies have assessed contextual-level motivation for physical activity,[22,49] which can be contrasted from situational motivation which immediately precedes engaging in a physical activity as well as the proximal consequences that ensue.[55] Arguably, situational regulations would be more sensitive to momentary and daily fluctuations that can be captured using the ESM. Therefore, we extend past research with the third and main purpose of this study to examine associations between situational motivational regulations and levels of positive affect. As a final investigation point, researchers have presented evidence that SDT's regulations may have interesting associations with physical activity intensity.[51,56,57] For instance, Duncan *et al.*[56] found that IM, IJ and ID were all positively associated with physical activity intensity in women. Therefore, the links between the regulations and RPE will also be explored across time in the present study.

Purpose and hypotheses

The preliminary objective of this 14-day experience sampling investigation was to examine the relationship of pre-physical activity positive affect with levels of affect post- and 3-hours post-physical activity. Consistent with Reed and Ones,[19] it was expected that positive affect pre-physical activity would show a significant positive association with post-physical activity positive affect and that this latter variable would in turn be positively associated with affect three hours later, albeit to a lesser extent. Another aim of this study was to test the association between RPE and positive affect, which was expected to be significant and positive immediately after physical activity and weaker but still positive three hours after.[19,27] The main purpose of this investigation was to examine the influence of situational motivation on changes in positive affect from pre- to post- to 3-hours post-physical activity. Based on SDT and aforementioned research, it was hypothesized that IM and ID regulation would be positively related to positive affect post-physical activity as well as 3-hours post-physical activity while IJ and EX regulation would be unrelated or negatively related at either time point. The influence of the regulations on RPE was explored in a final, supplemental purpose. The self-determined regulations (*i.e.*, IM, ID) as well as IJ were expected to be positively associated with RPE while EX regulation would show no relation.[56]

Materials and Methods

Context

This study was part of a larger project examining the complex relationships between psychosocial variables, patterns of physical activity and non-physically active leisure, as well as indicators of well-being in active adult women with multiple life roles.[58] Therefore, any participant selected for this larger investigation conformed with the following inclusion criteria: i) female and mother with one child still living in the home ii) between the ages of 25 and 55, iii) active (*i.e.*, meeting the Canadian Guidelines of a minimum of 150 minutes of moderate to vigorous physical activity per week);[59] iv) employed full time (quantified as a minimum of 30 hours/week); v) reporting no underlying medical condition at the time of recruitment that would influence physical activity levels or impair mood.

Participants

Participants were recruited by means of posters on bulletin boards across several athletic centers and sport and children's stores as well as through professional and athletic electronic newsletters. Word-of-mouth recruitment and snowball sampling were also employed. Interested participants contacted the researchers via telephone or email to obtain information and to confirm that they met the inclusion criteria. Although 97 women were recruited, the final sample consisted of 66 active women as 31 women did not meet one or more of the criteria, were unable to commit to the time requirements of the study, or could not be reached for scheduling. The final sample of women had a mean age of 42.56 years (SD=5.61). The participants were mostly Caucasian (89%), well-educated (83% with bachelor's degree or higher) and had an average of two children (SD=0.93) with a mean age of 10.42 years (SD=4.97). The women were also very active overall, with a mean score of 59.71 (SD=21.01) on the Godin Leisure Time Exercise Questionnaire (LTEQ),[60] and they had a healthy BMI of 22.59 on average (SD=2.68).

Procedures

Baseline session

Eligible participants began the study by attending an individual research session at a campus laboratory space. After being informed of the study purpose and protocol, written consent was obtained and participants completed the baseline measures. The researchers downloaded and programmed a questionnaire application to either the participant's own device or to an iPod Touch© that was supplied by the researchers for the 2-week experience sampling portion of the study. Two weeks is considered adequate to represent an individual's daily life.[61] The Apple© application in question was developed for iPod Touches and iPhones© in order to administer the questionnaires in such a way that would maximize procedural ease and consistency across participants. A short information period was given regarding how to use the device and the application. For those borrowing an iPod, more detailed instructions and practice were offered until participants felt comfortable with the device. Participants were also given specific instructions regarding electronic questionnaire requirements for the three time points of interest (*i.e.*, pre-, post, 3-hour post-physical activity).

Experience sampling

Participants were instructed to begin the next day and to model their habitual behavior over the 2-week period, including any lapses or surges in PA. Using an event-contingent experience sampling schedule,[13] participants responded to sets of questionnaires at three uniform time points, namely pre-, post-, and 3-hours post-physical activity, for each moderate-to-vigorous physical activity session they engaged in over the 14-day period. The first screen of the above-mentioned application was comprised of a questionnaire menu with an option for each of the three time points. The *Pre-Physical Activity* questionnaire consisted of assessments of motivation and positive affect while the *Post-Physical Activity* questionnaire consisted of three physical activity description questions followed by a measure of positive affect. Selecting the *3-hour Post-Physical Activity* questionnaire option asked participants to rate their positive affect once again. A *submit questionnaire* option appeared at the end of each question set, after which participants could no longer view or modify their responses. Questionnaires were timed out after 30 minutes.

Participants received an automatic reminder signal on their device three hours after filling out a post-physical activity questionnaire. To maximize responding, participants were advised that the 3-hour post-physical activity questionnaire could also be completed from the menu prior to- or after the reminder prompt, should it be within a 2.5-3.5 hour window. However, several participants engaged in physical activity in the evenings before bed, and as such, many 3-hour post-physical activity questionnaires were not completed. All responses for each time point were submitted through a safe and password protected server and were time- and date-stamped upon entry. The researchers downloaded individual datasets as Excel files. All procedures were approved by the University of Ottawa Institutional Review Board.

Endpoint session

Participants returned to the laboratory after the two weeks in order to return the device (if necessary) and so that the researchers could ensure that all data was properly transferred through the server and deleted from the device. Participants were offered a 15$ gift card for their involvement in the study and they were debriefed and invited to pose questions and raise any issues they had experienced with the application.

Measures

Baseline descriptives

A demographic questionnaire was employed in order to obtain a general description of the sample of women. In addition to questions pertaining to employment, ethnicity, children, etc., the LTEQ was administered in order to quantify activity levels of the participants for descriptive purposes.[60] The LTEQ is a valid and reliable measure of physical activity across different populations.[62] Participants were to indicate the number of times in the last six months they had engaged in strenuous, moderate, and light activity. Definitions of each type were provided. To create a summary score, each number was multiplied by its corresponding MET value of nine, five, and three for vigorous, moderate and light respectively.

Experience sampling: situational motivation

Three subscales from the original Situational Motivation Scale (SIMS)[63] were administered to assess the motivational regulations of interest prior to each self-reported physical activity session over the 2-week period. Specifically, 12 original items from the SIMS were used to evaluate levels of IM, EX, and ID regulations.[64] Although IJ regulation was excluded from the original SIMS for brevity,[63] Gillet and colleagues have developed a four-item subscale for IJ that can be integrated into the SIMS.[65] The items in this subscale have demonstrated adequate factor loading and good internal consistency values (*e.g.* α=0.85).[51,65] Given the interest in this regulation in the present study, this subscale was also employed.

Each item was answered on a 7-point Likert Scale from [1] corresponds not at all to [7] corresponds exactly using the stem *why are you currently about to engage in exercise.*

For example, one item assessing IJ regulation is *[...] because I would regret not doing it.*

Mean scores for IM as well as ID, IJ, and EX regulations were calculated for each recorded physical activity session. The SIMS has demonstrated adequate psychometric properties in previous studies.[63,64,66] The Cronbach's alpha values in the present study for each subscale across participants and exercise sessions ranged from 0.73 to 0.91.

Experience sampling: positive affect

The positive affect subscale of the Positive and Negative Affect Schedule (PANAS)[67] was employed to assess positive affect at all time points over the two weeks (*i.e.*, Pre-, Post-, 3-hours Post-exercise). [The full PANAS including the negative affect subscale was administered. Although the alpha level of the negative affect subscale was adequate across time points, the distributions of the data showed significant positive skew (*i.e.*, half of participants scored the minimum value or very low). Since issues with negative affect have been reported in other physical activity studies,[41,68] and given the importance of positive affect in this context, analyses of negative affect were not conducted for the present paper.]

The PANAS is a measure of high activation affect that has been frequently employed as a valid and reliable measure of affective states in studies of exercise behaviour as well as in the SDT literature.[19,69] High activation affect refers to an energetic state (or excitation) which is most relevant in the context of acute physical activity, in contrast to low activation affect which refers to a calm, relaxed and/or depressed state.[70] For each of ten adjectives that represent positive affect, responses to the stem *Indicate to what extent you feel this way right now* were rated from [1] not at all to [5] extremely. The sum of the ten items, for example *excited* and *interested*, was computed for each questionnaire time point. High internal consistency values for the positive affect subscale pre- (α=0.93), post- (α=0.91) and 3-hours post-exercise (α=0.93) were demonstrated.

Experience sampling: activity description

Participants were asked to provide the following information after each physical activity session that was logged: The amount of time (in minutes) they had engaged in PA, a basic description of the type of physical activity that was completed (30 characters maximum), and an indication of the intensity of the physical activity. The latter was assessed using a session Rating of Perceived Exertion (RPE),[71] which is a reliable measure of intensity in exercise-based studies of affective states.[72] The RPE is a self-report instrument made up of descriptors at every odd integer on a 6-20 scale (*i.e.,* 7=very, very light; 13=somewhat hard; 19=very, very hard).

Analyses

Preliminary

Baseline descriptive data were entered directly into SPSS Statistics 20 and summary statistics were computed. The experience sampling data had to be exported from Excel to SPSS. Afterwards, the sums and means of these questionnaires were computed for each of the respective time points and subscales. Averages across time points were also calculated for descriptive purposes (*e.g.,* pre-physical activity positive affect, IM, ID, etc.). The following questionnaire entries were deleted: any pre-physical activity or post-physical activity entries that did not occur within a plausible time frame specified in a participant's post-physical activity description as well as 3-hour post-physical activity entries that occurred within two hours of the post-physical activity recording or later than four hours post-physical activity. Reponses to the 3-hour post-physical activity questionnaires were also eliminated if a new pre- questionnaire (*i.e.*, a new session) was answered between the post- and the 3-hour post- questionnaires.

Hierarchical linear modeling

The ESM produces data with a hierarchical structure therefore the data was restructured to be analyzed in hierarchical linear modeling (HLM) 6.0 statistical software.[73,74] Each participant could log a unique number of physical activity sessions and therefore it was not possible to have physical activity sessions at level 2 with time (pre-, post-, 3-hour) as a within-person level 1 variable. Therefore, level 1 consisted of the dependent variable (positive affect), the predictor variables for each session, namely pre-physical activity positive affect (and post- for 3-hour analyses), motivational regulations, as well as RPE values. These were grouped by the level-2 variable: participant. In several ways, HLM is ideally suited for this dataset. First, the level 1 observations of each individual are not independent which would violate a major assumption of traditional ordinal least-squares (OLS) regression techniques.[75] Second, multilevel models can account for uneven time intervals between responses as well as different number of responses from participants.[13,76] Third, HLM can handle large amounts of missing data, and even with small samples, it can provide reliable estimates of within-subject relationships.[10] There is ongoing debate regarding complex power calculations for HLM.[77] That said, sample size the current study was consistent with that of past research and with expert recommendations.[16,78-80]

As suggested by Raudenbush *et al.*[72,73] and other researchers,[78] we used a step-up procedure where the first model that was tested did not include predictor variables (*i.e.*, unrestricted model). Then, various restricted models with combinations of variables were tested to address study hypotheses. All level 1 predictors were group-mean centered, with group referring to participant (Level 2). The sample of equations below illustrates the analyses. Level 1 represents participants' rating (subscript *i*) of post-physical activity positive affect (Y_{pi}) at any given physical activity session (subscript *p*). [Additional symbols in the sample equations can be interpreted as: β_{0i}=intercept of post-physical activity affect in participant *i*; β_{1i} and β_{2i}=slope of relationship between level-1 predictor variable and post-physical activity affect in participant *i*; e=random error; γ_{00}=overall intercept expected for post-PA positive affect at the mean of pre-PA affect across participants; γ_{10}=overall slope of relationship between pre-PA positive affect and post-PA affect across participants (γ_{20}=same for RPE); u_0 and u_1=residual variances.]

The person-specific intercepts and slopes are then modeled at Level 2.

Level 1: Post-physical activity positive affect $(Y_{pi})=\beta_{0i}+\beta_{1i}$ (pre-physical activity affect_{pi}) $+\beta_{2i}\,(RPE_{pi}) + e_{pi}$.

Level 2: i) $\beta_{0i}=\gamma_{00}+u_{0i}$; ii) $\beta_{1i}=\gamma_{10}+u_{1i}$; iii) $\beta_{2i}=\gamma_{20}+u_{2i}$.

Similar equations were used for the motivational regulations and post-physical activity affect.

Level 1: Post-physical activity affect $(Y_{pi})=\beta_{0i}+\beta_{1i}\,(\text{Intrinsic}_{pi}) + \beta_{2i}(\text{Identified}_{pi}) + \beta_{3i}(\text{Introjected}_{pi}) + \beta_{3i}(\text{external}_{pi}) + e_{pi}$.

Level 2: i) $\beta_{0i}=\gamma_{00}+u_{0i}$; ii) $\beta_{1i}=\gamma_{10}+u_{2i}$; iii) $\beta_{2i}=\gamma_{20}+u_{2i}$; iv) $\beta_{3i}=\gamma_{30}+u_{3i}$; v) $\beta_{4i}=\gamma_{40}+u_{4i}$.

For equation set 2, any situational regulation found to be significantly associated with post-physical activity affect was then modeled individually while also accounting for pre-physical activity affect and RPE. Similar equations were treated in examining the influence of the regulations on RPE (with and without pre-physical activity affect) as well as for all analyses of 3-hour post-physical activity positive affect as the dependent variable. As shown in equation sets 1 and 2, intercepts and slopes were set as randomly varying in all initial analyses. Parameters were then revised to be fixed if their coefficients were estimated with low reliability or if random errors terms were not significantly different between participants.

Hypotheses were tested using t-ratios that indicate the significance of the respective coefficients in the different models. In addition, HLM includes a log-likelihood test of the fit improvement of variance-covariance structures with previous models (using χ^2). This was employed to examine which models were superior with the inclusion of additional variables or variances.[74,77] The full-maximum likelihood estimation was used as it is deemed suitable for model comparison.[81] To help with interpretation, pseudo-R^2 was calculated as a measure of effect size. Specifically, the unexplained variance from a restricted model is subtracted from that of an unrestricted model and then divided by the unexplained variance in the unrestricted model.[72,80]

Results

Data cleaning and summary

Due to recording and data transfer error, the experience sampling data from three participants had to be eliminated. The remaining 63 women who contributed ESM data were not significantly different from the original sample of N=66 [Age=42.60 years (SD=5.59), BMI=22.70 (SD=2.81), LTEQ=59.86 (SD=21.36, range: 14-130].

Aggregate scores across participants for the motivational variables, RPE, and positive affect at the three time points as well as the number of data points for each are reported in Table 1.[82,83] Discrepancies in the number of data points across variables are either: i) a reflection of skipped recordings by participants at one or more of the possible time points or ii) the result of data-cleaning by the researchers. Specifically, any problematic pre-physical activity questionnaires, post-physical activity PANAS entries, and 3-hour post-physical activity questionnaires were eliminated based on aforementioned criteria (Table 1).

The distributions of the variables were examined in terms of skewness and kurtosis. Mahalanobis distances, multicollinearity and any remaining customary assumptions of univariate and multivariate regression analyses were also tested.[84] One outlying value for RPE was identified and given one point less than the next lowest value in the distribution. Afterwards, a log transformation was applied to the RPE variable as its distribution remained positively skewed. Lastly, graphing residual variances of the 3-hour data revealed one multivariate outlier. This participant's data were removed from further analyses involving the 3-hour time point. No other deviations from normality were observed. Robust standard errors were evaluated in all HLM analyses. The unstandardized coefficients of noteworthy models are presented in Tables 2 and 3. To ease the presentation of complex analyses and models, the results below are organized longitudinally by time point rather than conceptually as they appeared in the Purpose section. All results for RPE pertain to the transformed variable unless otherwise stated.

Post-physical activity positive affect

To put the women's physical activity into context, they logged an average of 10.62 sessions each over the 2-week period (range: 5-20), with some reporting 2+ physical activity sessions per day. Participants recorded an average of 59.60 minutes per session (SD=38.44; range: 20-180) and an average RPE of 14.53. A wide variety of physical activity descriptions/types were reported, such as running, swimming, spinning, hiking, and skiing.

Preliminary purpose and ratings of perceived exertion

The unrestricted model for post-physical activity positive affect revealed that the average on this outcome variable was high (M=34.62). In the first restricted models that were tested, there was a significant, positive association between pre-physical activity and post-physical activity affect, $t(61)=7.86$, $P<0.001$, which varied between participants. There was also a significant positive relationship between session RPE and post-physical activity positive affect, $t(605)=5.85$, $P<0.001$, and this fixed effect remained significant even after accounting for levels of pre-physical activity affect. Pre-physical activity positive affect explained a greater proportion of variance (27.3%) compared to RPE (7.1%). The model with both variables, labeled Model 1 in Table 2, was a better fit compared to pre-physical activity affect as the sole predictor, $\chi^2(1)=96.38$, $P<0.001$, and this model explained a total of 33.8% of the variance in post-physical activity affect (*i.e.*, pseudo R^2).

Table 1. Descriptive statistics of experience sampling variables: motivational regulations (pre-exercise) and positive affect.

	N.	Mean	SD	ICC
Situational intrinsic motivation	635	5.32	1.25	0.55
Situational identified regulation	635	5.98	0.83	0.63
Situational introjected regulation	635	4.11	1.79	0.77
Situational external regulation	635	3.13	1.64	0.76
Rating of perceived exertion regulation (log transformation)	599	14.53 (1.16)	2.08 (0.06)	0.30 (0.28)
Pre-exercise affect	626	30.75	8.03	0.55
Post-exercise affect	588	34.82	7.26	0.54
3-hours post-exercise affect	390	30.23	8.40	0.50

SD, Standard Deviation; ICC, Intra-class correlation.
Excluded questionnaires based on criteria outlined in main text: 6 *Pre-Exercise* questionnaires, 14 *Post-Exercise* PANAS entries, and 83 *3-hour post-exercise* questionnaires. A total of 22 recorded PA sessions also removed due to RPE values that fell below a moderate intensity cut-off, as suggested by experts.[82,83]

Main purpose: motivation

Next, models were tested to predict post-physical activity positive affect using the situational motivational regulations (fixed). Although EX, IJ, and ID regulations did not show significant associations with the outcome variable, *t*s:-1.27 to 0.33; $P>0.05$, the slope for IM was significant, $t(603)=3.14$, $P<0.01$. In this case, for every one unit increase in IM, there was a 1.26 point increase in positive affect. The model with the regulations explained 5.8% percent of the within-person variance in post-physical activity affect. When a model was tested with IM only (accounting for the influence of positive affect pre-physical activity and RPE), the influence of IM remained significant, $t(543)=2.09$, $P<0.05$. The comprehensive model (Model 2-B in Table 2) explained 34.7% of the variance in post-physical activity positive affect and provided a superior fit than either IM alone, or pre-physical activity affect and RPE excluding IM, $\chi^2s>5.0$, $P<0.05$.

Next, the associations between the motivational regulations and RPE were examined. First, a test of the basic model with just the regulations showed that only IJ regulation was significantly and positively associated with RPE, $t(603)=3.38$, $P<0.001$. T-ratios and significance values were almost identical with the untransformed RPE variable, which offers more meaningful interpretation. In this case, the slope coefficient reflects a resultant 0.28 point increase in RPE (untransformed) with every one-unit increase in IJ. As can be seen from Models 3-A and -B in Table 2, this effect remained significant, $t(544)=4.28$, $P<0.001$, even after accounting for the effect of incoming positive affect. The model with pre-PA affect and IJ regulation together provided the superior fit and it explained 6% of residual variance in RPE.

Three-hours post-physical activity affect

Preliminary purpose and ratings of perceived exertion

The unrestricted model for 3-hours post-physical activity positive affect revealed that the average on this variable was high ($M=30.18$), albeit it represents a drop from immediately post-physical activity [aggregate scores: $t(60)=8.11$, $P<0.001$]. In the first restricted model (not shown in Table 3) there was a significant association between post-physical activity and 3-hours post-physical activity positive affect, $t(588)=2.43$, $P<0.05$; this slope was set to fixed as it was not found to vary significantly between participants, $\chi^2(52)=67.52$, $P=0.07$. As shown in Model 1 (Table 3), this effect remained significant after accounting for the fixed effect of positive affect levels prior to engaging in PA, $t(589)=2.15$, $P<0.05$. The model with both pre- and post-physical activity positive affect provided a better fit than post-physical activity affect alone, $\chi^2(1)=121.37$, $P<0.001$, and this explained just over 3% of the variance in affect three hours after exercise. There was also a significant positive relationship between session RPE and 3-hours post-physical activity positive affect, $t(588)=1.91$, $P<0.05$, however, this fixed effect became non-significant after accounting for levels of pre- and post-physical activity affect, $t(588)=1.10$, $P=0.27$. Still, the model with all three predictor variables provided the best model fit ($P<0.001$ for all χ^2 comparison tests) and it explained 4% of variance in 3-hour post physical activity affect (Model 2 in Table 3).

Main purpose: motivation

Lastly, we examined the predictive ability of the motivational regulations (fixed) with respect to 3-hours post-physical activity positive affect. While neither IM, EX nor IJ regulations were significantly associated with the outcome variable, $ts<0.05$, $P>0.05$, the slope for situational ID regulation ($\beta=1.25$, $SE=0.60$) was significant, $t(590)=2.08$, $P=0.038$, but only when the other regulations were excluded (not shown in Table 3). When we tested a model with ID as the only regulation, again controlling for the influence of positive affect levels immediately pre- and post-physical activity as well as RPE, the positive influence of ID remained significant, $t(587)=1.91$, $P=0.05$. This comprehensive model (Model 3-B, Table 3) explained 5.0% of the variance in 3-hours post-physical activity positive affect and provided a superior fit than ID regulation alone, $\chi^2(3)=251.73$, $P<0.001$ and a slightly better fit than the pre-post affect and RPE model not including ID, $\chi^2(1)=3.42$, $P=0.06$.

In sum, intrinsic motivation, positive affect before physical activity, and RPE were positively associated with positive affect immediately after physical activity. Only introjected regulation was associated with RPE. Positive affect three hours post physical activity was positively predicted by affect pre- and post- and slightly by RPE. Only identified regulation was associated with positive affect three-hours after physical activity.

Discussion

The main purpose of this 14-day experience sampling study was to examine, among active

Table 2. Models predicting levels of post-physical activity positive affect.

Model	Coefficient	SE	Model	Estimate	SE
1. RPE and pre- with post-affect					
Fixed effects					
Intercept, β_{00}	34.87*	0.74			
Pre- affect, β_{10}	0.35*	0.05			
RPE β_{20}	22.28*	3.63			
Random effects[a]					
Intercept, σ^2_{u0}	31.28*	5.59			
Pre- affect, σ^2_{u1}	0.06*	0.25			
Residual variance, e	16.71	4.09			
2A. Regulations with post-affect			2B. Intrinsic motivation with post-affect		
Fixed effects			Fixed effects		
Intercept, β_{00}	34.82*	0.73	Intercept, β_{00}	34.87*	0.74
Intrinsic motivation, β_{10}	1.26**	0.40	Pre- Positive Affect, β_{10}	0.32*	0.05
Identified regulation, β_{20}	0.17	0.52	Intrinsic motivation, β_{20}	0.59***	0.28
Introjected regulation, β_{30}	0.12	0.39	RPE, β_{30}	22.86*	3.45
External regulation, β_{40}	-0.40	0.31			
Random effects[a]			Random effects[a]		
Intercept, σ^2_{u0}	29.90*	5.47	Intercept, σ^2_{u0}	31.33*	5.60
Residual variance, e	23.79	4.88	Pre- positive effect, σ^2_{u1}	0.07**	0.26
			Residual variance e	16.45	4.06
3A. Motivation with RPE[b]			3B Introjected regulation with RPE[b]		
Fixed effects			Fixed effects		
Intercept, β_{00}	1.157	0.005	Intercept, β_{00}	1.157*	0.005
Intrinsic motivation, β_{10}	-0.000	0.003	Pre- Positive Affect, β_{10}	0.002*	0.000
Identified regulation, β_{20}	0.005	0.005	Introjected regulation, β_{20}	0.010*	0.002
Introjected regulation, β_{30}	0.009*	0.003			
External regulation, β_{40}	-0.002	0.003			
Random effects[a]			Random effects[a]		
Intercept, σ^2_{u0}	0.001*	0.03	Intercept, σ^2_{u0}	0.001	0.033
Residual variance, e	0.002	0.05	Pre- positive affect, σ^2_{u1}	0.000	0.001
			Residual variance, e	0.003	0.050

Coefficient, unstandardized estimates; SE, Standard Error; RPE, Ratings of Perceived Exertion. All RPE values based on the log transformed variable; Models 3-A and 3-B are reported to three decimal places given low coefficient values with the RPE as the transformed dependent variable.
[a]Variance component estimates and standard deviations are provided for Random effects.
[b]Coefficients with untransformed RPE [Model 3-A]: $\beta_{00}=14.50$ ($SE=0.17$); $\beta_{10}=0.00$ ($SE=0.11$); $\beta_{20}=0.16$ ($SE=0.18$); $\beta_{30}=0.28$ ($SE=0.09$); $\beta_{40}=-0.04$ ($SE=0.11$). [Model 3-B]: $\beta_{00}=14.49$ ($SE=0.16$); $\beta_{10}=0.06$ ($SE=0.01$); $\beta_{2}=0.32$ ($SE=0.07$).
*P<0.001, **P<0.01, ***P<0.05.

women who were also working mothers, the influence of situational motivation on changes in positive affect from pre- to post- to 3-hour post-physical activity. A secondary objective was to investigate the association between the perceived intensity of physical activity (*i.e.,* RPE) and positive affect at the given time points. A strong feature of this study was the use of the ESM and thus the capacity to capture natural patterns of physical activity engagement and positive affect in the lives of busy, active women. Compared to cross-sectional and laboratory studies, experience sampling offers advantages in terms of reducing retrospective self-report bias and memory reconstruction errors as well as enhancing external validity. Although other studies in this area have been carried out using ESM protocols ours offers several unique components.[28,43] Specifically, we i) used a sound theoretical framework of motivation (*i.e.*, SDT) to ground our enquiries and we also focused on the proximal effects of situational motivation for each physical activity session. The latter is consistent with Vallerand's hierarchical model of motivation, namely that a given outcome (*i.e.*, physical activity affect) should correspond to the level of motivation that produced it.[55] We also ii) capitalized on the longitudinal aspects of the ESM by repeatedly measuring affect at three activity-related time points (pre, post-, 3-hours post-), which to our knowledge has never been done. Finally, we iii) recruited active, multiple-role women rather than use a student-based convenience sample given that the former group remains understudied despite accruing unique emotional benefits from physical activity.[9]

With respect to the preliminary objective of this study, there was a positive relationship between positive affect pre- and post-physical activity, with higher levels reported post. This moderate effect was similar to other studies employing the PANAS in all-women samples.[11,85] This lends added support for the importance of considering individuals' baseline affective states when examining the influence of physical activity, either in research or in interventions.[22,86] Our results also showed a positive association between post-physical activity positive affect scores and those 3-hours post. In other words, the better the women felt immediately after physical activity, the better they felt hours later. However, participants did present lower scores on positive affect 3-hours post-physical activity compared to directly post-physical activity. This drop is not unlike the results obtained by Cox *et al.*[27] for moderate-intensity physical activity. Still, other studies and older experimental research have found that exercise-enhanced affective states (*i.e.*, above baseline levels) do generally persist for three to four hours.[27,85,87] Our naturalistic data suggests that this might not necessarily be the case, or rather, that it may be relative to positive affect levels achieved post-activity. Our findings and those of others, for example,[85] seem to support propositions that the effect of physical activity can last, but that it is relative, variable, and diminishes over time.[19]

Another aim of this investigation was to clarify the relationship between the perceived intensity of physical activity and positive affect, doing so in natural physical activity environments over a 2-week period. We found that RPE was associated with greater levels of post-physical activity positive affect and thus we conclude that the more intensely the participants perceived they were engaging in their activity, the better they felt psychologically afterwards. These results add support for similar conclusions with active individuals.[51,82] We also found that the effect of RPE diminished 3-hours post-physical activity. Using an objective measure (VO_2 max), one study saw that at high compared to moderate intensity, positive affect was more sustainable 90-minutes post-physical activity and was higher than baseline.[27] However, this environment was very controlled. Clearly, more studies need to be conducted for further elucidation. Thus far, the results of this investigation confirm the beneficial influence of physical activity on an important indicator of mental health (*i.e.*, affect) and suggest that having women engage in higher intensity physical activity may be particularly beneficial emotionally.

The main purpose of this study was to investigate the role of situational motivational regulations from SDT on the relationship between physical activity and positive affect at three activity-related time points. This was the first ESM study to do so. Overall, the results reveal a viable sequence of influence whereby different types of motivational regulations lead to distinct outcomes that are experienced over time. To explicate, IJ seems to arise as a short-term factor *during* physical activity with its impact on RPE. Next, IM and RPE (*i.e.*, higher intensity physical activity) provide immediate

Table 3. Models predicting levels of 3-hour post-physical activity positive affect.

Model	Coefficient	SE	Model	Estimate	SE
1. Pre- and post- with -3-hours post affect			2. RPE with 3-hours post affect		
Fixed effects			Fixed effects		
Intercept, β_{00}	30.25*	0.86	Intercept, β_{00}	30.31*	0.87
Pre- affect, β_{10}	0.07	0.07	Pre- affect, β_{10}	0.07	0.08
Post- affect, β_{20}	0.22**	0.10	Post- affect, β_{20}	0.18	0.10
			RPE, β_{30}	6.39	6.91
Random effects			Random effects		
Intercept, σ^2_{u0}	36.08*	6.01	Intercept, σ^2_{u0}	36.68*	6.06
Residual variance, *e*	32.30	5.68	Residual variance, *e*	32.20	5.67
3A. Motivation with 3-hours post affect			3B. Identified regulation with 3-hours post affect		
Fixed effects			Fixed effects		
Intercept, β_{00}	30.23*	0.87	Intercept, β_{00}	30.31*	0.87
Intrinsic motivation, β_{10}	0.39	0.51	Pre-positive affect, β_{10}	0.05	0.07
Identified regulation, β_{20}	1.02	0.65	Post-positive affect, β_{20}	0.18	0.10
Introjected regulation, β_{30}	0.38	0.46	RPE, β_{30}	6.22	6.94
External regulation, β_{40}	0.11	0.49	Identified regulation, β_{40}	1.32**	0.69
Random effects			Random effects		
Intercept, σ^2_{u0}	37.55*	6.13	Intercept, σ^2_{u0}	36.78	6.06
Residual variance, *e*	33.01	5.75	Residual variance, *e*	31.78	5.64

Coefficient, unstandardized estimates; SE, Standard Error; RPE, Ratings of Perceived Exertion. All RPE values based on the log transformed variable.
[a]Variance component estimates and standard deviations are provided for Random effects.
*P<0.001, **P<0.05

bursts of positive affect post-physical activity and lastly ID regulation appears to foster delayed or long-term effects on positive affect. In the paragraphs that follow, we discuss each link of the sequence in turn.

As expected, IM was significantly associated with an increase in positive affect from pre- to post-physical activity, even after controlling for RPE, which supports that when women engage in their day-to-day physical activity out of enjoyment, they reap immediate emotional benefits.[49] This complements findings from a study with female gymnasts that revealed that IM was related to pre- and post-practice affect as well as vitality.[54] The given link is coherent with SDT in that IM's characteristic properties foster an orientation that predicts positive outcomes.[40] Conversely, our results revealed a non-significant association between EX and positive affect, despite it being in the expected negative direction. This is in line with SDT as well as with conclusions arising from other studies that suggest that the impact of this regulation may be negligible in an active sample.[35,38,56]

Still within the focal objective of this study, IJ regulation was not directly associated with positive affect, either immediately post-physical activity or three hours later. This runs contrary to Guérin and Fortier who in a laboratory setting found that IJ predicted an increase in positive affect,[11] possibly due to an experimentally induced sense of obligation. However, the finding *is* similar to Kwan and colleagues who in a naturalistic study saw no correlation between IJ and positive affective states with exercise.[49] The absence of an association is also consistent with the theoretical tenants of SDT, namely that internally controlled behaviors should not predict organismic wellness.[40]

Unlike introjection, ID regulation is argued to be important for persisting in behaviors that are valued but that are not always inherently pleasurable, such as exercise.[44,88] Most importantly for the present study, previous literature has shown ID regulation for physical activity to be related to enduring indicators of well-being such as physical self-worth and life satisfaction.[35,89] In our sample of women, situational ID regulation was not significantly related to post-activity positive affect. However, and most interestingly, ID regulation held a notable influence on positive affect 3-hours post-physical activity. That is, the more the women identified and valued physical activity when engaging in it, for health benefits for instance, the better they felt hours afterwards. Still, this finding resonates with SDT's contention that the more an individual internalizes an activity, the more she can reap its psychological benefits.[90] In our study, affective benefits of ID appeared hours after partaking in physical activity. To our knowledge, this is the first study to reveal such a finding as little research has directly linked SDT constructs with affective indicators of well-being, either situationally or over time.[91]

Finally, with respect to our supplemental purpose to explore the links between motivation and physical activity intensity, IJ regulation was significantly related to RPE, as predicted. In short, the more the women in our sample engaged in physical activity to avoid feeling guilty or shameful the more intensely they exerted themselves. A similar association between introjected motives and physical activity intensity was noted by Duncan *et al.*[56] as they discussed evidence that women often feel a need to exercise more intensely. If we consider that in our study RPE was associated with better post-physical activity affect, this pattern is not necessarily maladaptive. However, research suggests that the short-term influence of an IJ style could degenerate in one of two ways. Either persistence in physical activity could wane over time, as per Pelletier and colleagues,[48] thus resulting in fewer post-physical activity affective benefits, or a regimented and addictive pattern of exercise may develop, with unique dangers in terms of overall well-being.[92] Given the physical activity status of our sample, the latter may be more likely and thus careful future enquiry of the longitudinal relationship of IJ, as well as RPE, with indicators of well-being is required.

The sequence interpreted above is of distinct theoretical importance. It will be important in future studies to test these sequential postulates using complex path analyses. Perhaps mediational and moderational frameworks would help dissect these links, particularly the IJ-RPE-affect sequence. In addition, experts argue that the regulations are not mutually exclusive and that unique motivation combinations may best explain physical activity.[54,93] Building from previous motivational profile studies,[94,95] examining the combined effect of the regulations and RPE on activity-related affect would be a fruitful avenue of future enquiry.

The practical implications of the results could depend on the aims of an intervention. For women seeking the benefits of frequent bursts of positive affect, including those suffering from fatigue or acute depressive episodes, promoting enjoyable physical activity and pleasurable sensations from exercise (*i.e.*, IM) may be ideal. Moreover, educating and encouraging women to achieve high-intensity physical activity could facilitate rushes of positive affect, in addition to nurturing well-known physical benefits. In terms of stretching the affective benefits of physical activity over longer periods of time for added energy, wellness, and functionality in women's lives, promoting an ID style of motivation should be on the agenda. This may be achieved by marketing the health-benefits of physical activity and encouraging women to internalize its value. Alternatively, a combined approach targeting each of the regulations may be safer and best suited for general well-being promotion.

This study is not without its weaknesses. While the ESM certainly improved the relevance and external validity of the findings, timing and practicality issues led to some erroneous and/or missed entries and fewer assessments at the 3-hour time point specifically. This warrants that the results be interpreted (and generalized) with caution. Moreover, whether and when participants had truly engaged in physical activity as well as how long it lasted was not objectively corroborated. Tapping into the GPS function of the electronic devices and/or fastening the women with accelerometers for the duration of the study would have allowed for a) validation of physical activity reports; and b) teasing out the more physiological aspects of physical activity intensity in addition to subjective RPE. Similarly, no specific analyses were conducted on type of activity. It could be that cycling to work in heavy traffic as one's physical activity for a given day has different and more (or less) enduring effects on positive affect than an hour of intense skiing with one's partner or child. Finally, while the objective was to investigate the given motivational process in active women, future studies using mixed samples with diverse physical activity levels and mental health statuses should be undertaken to corroborate the transferability of the findings.

Notwithstanding these limitations, the results of this study support that physical activity is emotionally beneficial and that higher intensities can stimulate greater improvements. The findings are also suggestive of a novel motivational sequence that carries important theoretical and practical implications. This investigation brings us one step further towards uncovering the intricate relationship between physical activity and well-being.

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