HOW DO EMOTIONS AND FEELINGS REGULATE PHYSICAL ACTIVITY?

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HOW DO EMOTIONS AND FEELINGS REGULATE PHYSICAL ACTIVITY?

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Up to date the scientific discussion about how frequency and regularity of physical activity can be increased is dominated by social-cognitive models. However, increasing evidence suggests that emotions and feelings have greater influence on physical activity than originally assumed (Rhodes, Fiala, & Conner, 2009). Generally speaking, humans possess an evaluative system with a basic action tendency to approach pleasurable events and to avoid aversive ones (Cacioppo & Berntson, 1999). Evaluative responses to a behavior and associated emotional states may influence a decision regarding whether or not to repeat being physically active. Generally, behavior associated with positive evaluations has a higher probability of being repeated than behaviors without such an association. On the contrary, an association with negative evaluations tends to decrease the probability of repeating to be physically active. Hence, evaluative responses to physical activity or the related situation can be an important aspect in the process of physical activity maintenance (McAuley et al., 2007).

Several social-cognitive models of behavior change and maintenance were recently extended to take the influence of affective responses into account, in a way that variables already included in the models (e.g. outcome expectancies or attitudes) were more clearly articulated into their cognitive and affective components. For example, with regard to Social Cognitive Theory, Gellert, Ziegelmann and Schwarzer (2012) proposed to distinguish between affective and health-related outcome expectancies, and in the Theory of Planned Behavior, researchers suggested to differentiate between cognitive and affective attitudes (Lawton, Conner, & McEachan, 2009). The results of these and other studies suggest that affective components make a unique contribution to the explanation of the physical activity behavior (Brand, 2006). Other examples come from social cognition research, where it was shown that automatic evaluative responses are part of our everyday life and that they decisively influence health behavior (Hofmann, Friese, & Wiers, 2008). Accordingly, there is evidence that people who exercise regulary hold more positive automatic evaluations with exercise than non-exercisers (Bluemke, Brand, Schweizer, & Kahlert, 2010).

Although significant progress has been made in showing that evaluative responses to physical activity and associated emotional states are important predictors of physical activity underlying psychological processes are far from being fully understood. Some important issues still remain to be resolved. Which role play affective states compared to concrete emotions when influencing physical activity? How do affective states and emotions interact with cognitive variables such as intentions? Are evaluative processes before, during or after physical activity important to predict future physical activity? Do negative and positive evaluations interact antagonistically or rather synergistically when physical activity as a new behavior shall be adopted? Future research will help us to resolve these and a lot of other so far unresolved issues.

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Editorial: How do Emotions and Feelings Regulate Physical Activity?

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Keywords: physical activity, exercise, emotions, feelings, affect, regulation, implicit, enjoyment

Editorial on the Research Topic

How do Emotions and Feelings Regulate Physical Activity?

Intuitively, it is obvious that emotions and feelings influence our behavior. Therefore, it can be assumed that activities we like will be pursued with greater engagement and persistence than activities we do not like. When people feel good during or after physical activity, it can be expected that they will be more prone to repeat that behavior.

Despite this apparent relationship, affective states have been long ignored as a possible determinant of physical activity. In the last 15 years, however, the interest of researchers in affective determinants of physical activity erratically increased. Two reviews and meta-analyses have been conducted to summarize the empirical evidence for this relationship showing that only few longitudinal studies with remarkable methodological shortcomings exist (Rhodes et al., 2009; Rhodes and Kates, 2015). Furthermore, these reviews reveal that the underlying mechanisms are not well understood. For example, in 19 out of 20 identified experimental studies in the meta-analysis by Rhodes et al. (2009) affective variables were not influenced by the current intervention strategies. Only few studies used interventions explicitly targeting emotions and affective states to increase exercise adherence (Jekauc, 2015). Overall, it can be concluded that some empirical endeavors exist to analyze the role of affective states as determinants of physical activity but there are no fruitful theoretical frameworks to inspire research. The aim of this Research Topic is to make a contribution to close this research gap. It yielded 16 articles embedded in five strands of research. Firstly, three articles examined the role of affective variables within the scope of the social-cognitive perspective. Secondly, two articles proposed new theoretical approaches to understand the affective mechanisms in promotion of physical activity. Thirdly, four articles examined the determinants of affective variables. Fourthly, five articles examined the effects of affective variables on consecutive physical activity on a daily level using the methodology of ambulatory assessment. Fifthly, two articles examined non-conscious mechanisms by studying automatic evaluations. These five research strands are presented below.

One reason for the above mentioned shortage of theoretical development is that social-cognitive models dominated physical activity research for several decades (Jekauc et al., 2015). These models focused on cognitive mechanisms and neglected the role of affective states and emotions. More recently, researchers operating within the scope of *social-cognitive perspective* began to examine the role of affective variables. Klusmann et al. examined the role of emotional outcome expectancies

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within the framework of social-cognitive models and found that fulfillment of emotional outcome expectancies emerges as a significant predictor of adoption and maintenance of physical activity. Furthermore, two studies examined the role and the interdependencies of affective variables and self-efficacy in physical activity setting. Ungar et al. show that physical activity enjoyment was as strong predictor of physical activity level as self-efficacy in cancer patients. This study suggests that physical activity enjoyment has an independent and equal effect on physical activity level as self-efficacy. At the same time, Matsuo et al. provide evidence that post-exercise self-efficacy is related to subjective and objective measures of affectivestates indicating that self-efficacy and affective states are mutually dependent on each other. These three studies suggest that the effects of affective variables on physical activity are independent of self-efficacy whereas they both interact with each other at the same time. These studies imply that theoretical developments to extend social-cognitive models might be a promising way to examine the role of emotions and affects in physical activity maintenance.

Within the scope of this Research Topic, *alternative theoretical approaches* have been developed to understand the role of affective variables on physical activity. Lee et al. propose an evolutionary perspective hypothesizing that affective response to exercise will be more positive when the perceived immediate utility of the physical activity is high. The authors argue that promotion of activities which have an inherent utility like walking for transportation could be an effective strategy to increase physical activity levels. Furthermore, Murphy and Eaves discuss the hedonic perspective to explain the effects of affective variable on physical activity and point to the indiscriminant use of hedonistic terms in different areas of psychology and philosophy. Both perspectives provide innovative ideas which could be fertile for development of new intervention approaches beyond social-cognitive models.

A group of researchers examined with different methodological approaches the *determinants of affective variables*. Wienke and Jekauc examined the conditions of exercise under which enjoyment and positive emotions emerge. They discovered four factors, "perceived competence," "social interaction," "novelty experience," and "perceived physical exertion" which are associated with positive emotions. Independently, Sudeck et al. examined how two of these factors "perception of competence" and "perceived exertion" as well as "affective response to exercise" influence the development of affective attitude. The authors found out that perceptions of competence have a direct effect on changes in affective attitude whereas the effect of perceived exertion was indirect via positive activation influences on the development of affective attitude. Furthermore, Pilcher and Baker showed that physical activity at work on a stationary bike with a low level of exertion led to increases in positive affective states compared with the traditional work situation of sitting at an office desk. This study illustrates that low intensity physical activity at an active workstation increases positive feelings during work without having a negative effect on cognitive tasks. Rhodes and Mistry examined the reasons for anticipated regret over missing regular physical activity. The authors identified three dominating themes "missed opportunity to obtain the benefits of physical activity," "shame and guilt for not being able to follow-through with one's goals," and "perceived pressure from others." These studies can be used as a starting point for the development of innovative emotion-based interventions to promote physical activity.

An innovative methodological approach that examines the relationship between physical activity and affective states on a daily basis is the *ambulatory assessment method*. In a review conducted by Liao et al., six studies were identified that examined the relationship between affective states and subsequent physical activity. The findings suggest that positive affective states, for a few hours afterwards, were positively associated with physical activity while negative affective states had no significant association. These findings were confirmed in the studies by Niermann et al., Schöndube et al., Reichert et al., and Kanning and Schoebi which consistently showed that positive feelings and moods were positively associated with subsequent physical activity. In contrast to the findings of Liao et al., Niermann et al. found that negative affect decreased subsequent MVPA. This number of studies reflects the usefulness of the ambulatory assessment method for the examination of the relationship between affective states and physical activity. It illustrates how technological developments influence research in physical activity.

Another theoretical approach exceeding social-cognitive models represents the analysis of non-conscious processes such as *automatic evaluations*. Antoniewicz and Brand discovered that automatic evaluations of exercise at the beginning of an exercise program significantly predicts exercise adherence in the upcoming months. The study reveals the significance of non-conscious processes for maintenance of physical activity. Furthermore, Rebar et al. establish population-level evidence of the most common word stimuli for physical activity and pleasantness. These can be used as resources for response latency measurement tasks of automatic evaluations and as tools to enhance automatic evaluations of physical activity in evaluative conditioning tasks.

The aim of this Research Topic was to stimulate and pool systematic research on the role of emotions and feelings as predictors of physical activity. Several theoretical and empirical works contributed toward deepening the understanding of the working mechanisms.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

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Fulfilled Emotional Outcome Expectancies Enable Successful Adoption and Maintenance of Physical Activity

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Although outcome expectancies are regarded as key determinants of health behavior change, studies on the role of their degree of fulfillment in long-term activity changes are lacking. This study investigated the impact of (un-)fulfilled outcome expectancies (OE) on (un-)successful attempts to increase physical activity, assuming that disengagement is the logical consequence of perceived futility. Participants ($n = 138$) of a longitudinal cohort study with three measurement waves were assigned to eight different groups according to a staging algorithm of their self-reported, 1-year-long physical activity behavior track. Stages were validated by objective changes in objective fitness, e.g., Physical Working Capacity (PWC). Social cognitive variables, self-efficacy, proximal and distal OE, and fulfillment of OE, were assessed via self-report. Discriminant analyses revealed that OE fulfillment was the predominant predictor for differentiating between successful and unsuccessful behavior change. Amongst OE, proximal OE concerning emotional rewards, in conjunction with action self-efficacy, further improved discriminatory power. OE adjustment warranting hedonic rewards appears to be a crucial mechanism as it facilitates long-term changes through interventions aimed at increasing physical activity rates. Theoretical models might benefit by including the concept of fulfilled expectations acting in terms of feedback loops between volitional and motivational processes.

Keywords: fulfillment of outcome expectancies, emotional rewards, adoption of physical activity, maintenance of physical activity, stages of behavior, longitudinal cohort study, health behavior change process

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INTRODUCTION

Outcome expectancies (OE) attribute value to human action: Without expectations of resultant benefit, the likelihood of health behavior decreases. People might, for example, not question whether they could wear a helmet when riding a bicycle, but whether they decide to do so greatly depends on the belief that this is an effective tool for increasing safety. Thus, alongside self-efficacy beliefs (i.e., the self-conviction that someone is able to perform a behavior even in the face of obstacles and barriers), OE (i.e., providing the value of a behavior) are needed to enable people to form an intention to adopt a certain behavior (Bandura, 2001).

The readiness to act depends on the value of expected outcomes (e.g., Atkinson, 1957). As a core concept in enabling behavior changes, OE have long been established in common health behavior change models as, for example, perceived benefit in the Health Belief Model (Stretcher et al., 1997), behavioral beliefs in the Theory of Planned Behavior (Ajzen, 1991, 1998), or, more specifically, OE in the Health Action Process Approach (Schwarzer, 1992, 2008a). OE have the form of if-then assumptions (like "If I exercise, then I will. . . "). These refer to expected consequences of courses of action that differ in the degree of desire and probability (Heckhausen, 1977; Bandura, 2001). These expectations result from a contemplation process with a thorough balancing of pros and cons of anticipated behavioral outcomes. Classically, OE-values refer to positive psychological effects (e.g., fun, relaxation, companionship), body image (e.g., appearance, self-image, confidence), or health benefits (Steinhardt and Dishman, 1989; Schwarzer, 2008a).

Existing research has predominantly focused on self-efficacy beliefs, relegating OE the role of antecedents (Williams, 2010). This is surprising, given that OE were shown to be the most powerful predictor of intention in different longitudinal studies (Renner and Schwarzer, 2000), translating threat appraisals and risk perceptions into action (Renner and Schupp, 2011). Following a dynamic perspective (Renner et al., 2012a), OE are important for moving people from a pre-intending to an intending, that is, a pre-active stage of behavior change (Schwarzer, 2008a). OE are likely to remain important after individuals have formed an intention throughout the whole action process (see Fuchs, 1994). Although not specifying their direct effect on behavior, post-intentional changes of OE were assumed to determine the predictive power of the construct in the volitional phase (Schwarzer, 2008b). Specifically, proximal OE, comprising affective expectations directly related to emotional states during or directly after physical activity, predict physical activity behavior to a greater degree than distal OE, which encompass long-term consequences (Gellert et al., 2012).

In terms of a dynamic feedback loop, OE gain volitional relevance according to the degree of fulfillment: If our expectations are met, it is worth investing the effort. This loop fuels the behavior change process (Rothman, 2000; Fuchs, 2013; Loehr et al., 2014). However, the absence of desired outcomes leads to a deadlock where good intentions weaken or fade and a long-term change of habits becomes unlikely.

The World Health Organization (WHO, 2010) identified the lack of sufficient physical activity as the fourth leading risk factor for global mortality. Thus, raising physical activity levels is still an essential societal goal since for example in Germany more than 75% of the population do not meet common activity recommendations (Krug et al., 2013). Interventions designed to improve this key health behavior often fail to attain long-lasting changes in exercise behavior (e.g., Schwarzer, 2008a; Evers et al., 2012; Renner et al., 2012a). It has also been shown that affective attitude is a significant predictor of physical activity behavior (Conner et al., 2015) and positive activity experiences are important boosters for motivation and stamina (Klusmann et al., 2011). Positive exercise experiences were recently introduced as an additional predictor for changes in physical exercise levels over and above well-established social-cognitive variables (Fleig et al., 2011; Parschau et al., 2013, 2014). In line with the assumption on dynamic feedback loops, a study by Loehr and colleagues (2014) showed that daily-assessed positive physical activity experiences led to higher OE in the following week while negative experiences were followed by lower OE. Basen-Engquist and colleagues (2013) demonstrated that morning positive outcome expectancies were associated with subsequent exercise minutes at the same day, whereas negative outcome expectancies were not. Moreover, spontaneous enumeration of OE resulted in more positive OE (Rhodes and Conner, 2010). Thus, particularly positive emotional OE and their fulfillment might be important for successful adoption and maintenance of physical activity.

The aims of this study were (1) to assess behavior change trajectories concerning the adoption and maintenance of physical activity within the natural dynamics of social cognition and behavior in everyday life, (2) to validate these trajectories with objective indicators, and (3) to clarify the subjective social-cognitive dynamics of behavior change, focusing on the trajectories of those who attempted to become more physically active irrespective of the amount of objective physical activity. We assumed that if physical activity does lead to the expected outcomes, this boosts the behavior change process. In contrast, if expectancies are not met, behavior disengagement is a likely consequence.

Using longitudinal self-report activity data captured over 1 year and objective fitness parameters, the present study analyzes the dynamics between OE, OE fulfillment, and physical activity. As intended behavior initiation is critical to answering the pivotal question of whether OE come true, the target group comprised people with the attempt to become more physically active. To investigate behavior change dynamics within a real-life context, we assessed physical activity within a cohort study and in everyday life without additional interventions.

We developed a three-step staging algorithm to differentiate people with characteristic profiles of physical activity trajectories, based on classical approaches to assess behavior stages (see Prochaska et al., 1992; Schwarzer, 1992, 2008a; Weinstein and Sandman, 1992; for an overview and discussion see: Sutton, 2005). Further, we used direct measures, that is, people's self-evaluations of how successful were their attempts to translate intentions into action. This format fits with our aim to assess the social-cognitive dynamics in the behavior change processes and to clarify the role of OE fulfillment, which was similarly captured as evaluation of the degree of occurrence of previous expectations. In addition, the eight newly identified activity trajectory groups based on the staging algorithm were objectively validated by measured actual changes of physical fitness via bicycle ergometry. Finally, we examined the predictive power of the *fulfillment* of OE for successful real-life adoption and maintenance of physical activity over and above the well-established concepts of OE and self-efficacy beliefs.

MATERIALS AND METHODS

Participants

Data were collected as part of the Konstanz Life Study, a longitudinal cohort study of 1321 participants launched in spring 2012 (Renner et al., 2012b; Sproesser et al., 2015). As part of the

EATMOTIVE project, the Konstanz Life Study was funded by the Federal Ministry of Education and Research (BMBF Grant 0315671, granted to BR and Harald Schupp). Participants were recruited via flyers, posters, and newspaper articles. Waves 2 and 3 took place in autumn 2012 and spring 2013. All three waves, at intervals of about 6 months, captured objective health and fitness parameters as well as self-report variables focusing on physical activity and nutrition behavior. Participants received feedback on their objective health measures referring to current norms at each measurement point.

A bicycle ergometry was used to measure objective physical fitness. Thus, it was ensured that participants' blood pressure was in the normal range, i.e., systole below 150 mm HG and diastole below 100 mm HG, that participants neither suffered from a cardiovascular disease nor a history of cardiac infarction, nor a lung disease, metabolic disorder, or a mental disorder with medical advice to avoid physical exercise, nor epilepsy or multiple sclerosis, that participants did not undergo a current anti-tumor therapy, nor had a major intervention or surgery within the last 12 months, nor suffered another severe chronic or any acute disease, and that women were not pregnant. Participants had to be at least 18 years old. There were no further inclusion or exclusion criteria for the study.

Written informed consent was obtained, and the local ethical review board (University of Konstanz) approved the study protocol. The present study focuses on data captured at Waves 2 and 3, comprising 775 (58% female) and 511 (57% female) participants, respectively. All Wave 2 participants had attended Wave 1 and all Wave 3 participants had attended Wave 2. Age ranged from 19 to 87 years, mean (*SD*) age was 47.7 (17.4) for Wave 2 and 49.8 (16.9) for Wave 3. Mean (*SD*) BMI was 24.8 (3.9) and 24.8 (3.8); years of education, including years of school and years of training, were 15.8 (2.4) and 15.8 (2.4) for Waves 2 and 3, respectively.

The drop-out sample ($n = 264$) did not differ from the remaining 511 participants regarding the study variables (all $F < 3.64$, $p > 0.05$), BMI, $F_{(1,\ 482)} = 1.05$, $p = 0.31$, or the sociodemographic variables (gender, years of education; both $F < 0.47$, $p > 0.05$) except age. With a mean (*SD*) age of 43.7 (17.7), drop-outs were younger than the remaining sample, $F_{(1,\ 771)} = 21.96$, $p < 0.001$, $\eta^2 = 0.03$. This is due to the higher number of young participants at the onset of the study period and their dropping-out leads to a more equally distributed age of participants in the final sample.

Measures

Physical Activity Trajectories

A three-step staging algorithm was developed to assess different physical activity trajectories. In a first step at Wave 2, baseline stage (at Wave 1) was assessed retrospectively based on established criteria and validated items for stage assignment (e.g., Sutton, 2005; Lippke et al., 2009). In a second step, at Waves 2 and 3, participants assessed their behavior since the last measurement wave (Waves 1 and 2, respectively) and stated how successful eventual attempts to increase physical activity were.

Specifically, at Wave 2, participants were asked to retrospectively indicate their regular activity level before Wave 1 of the Konstanz Life Study on a five-point scale ranging from (1) *I had been active regularly for a longer period before,* (2) *I had tried to become active but did not succeed or had been active for a short period only*, (3) *I was not active but had thought about it,* (4) *I was not active and had not even thought about it,* to (5) *I was not active since it is not necessary to be active on a regular basis.* Participants who stated that they had either been active on a regular basis (1) or had tried to become active (2) were included in this study. Non-intenders (Schwarzer, 1992, 2008a) or (pre-)contemplators (Prochaska et al., 1992), or those who decided not to act (Weinstein and Sandman, 1992), that is, people without intentions or attempts to become more active were disregarded given that they did not enter the behavior change process.

Furthermore, at Waves 2 and 3 participants indicated whether they had increased physical activity since the last measurement point. Answers to the question "Since your last participation in the Konstanz Life Study, have you been more physically active than before?" were given on a four-point scale ranging from (1) *Yes, I became more physically active*, (2) *No, but I tried to become more physically active and did not succeed*, (3) *No and I have not (even) tried*, to (4) *No, because I was already active on a regular basis before*. Again we concentrated on participants who reported option 1 or 2 because they were assumed to have entered the volitional phase and presumably underwent the dynamic process of behavior change. Accordingly, characteristic activity trajectories of people who attempted to initiate or further enhance their physical activity behavior were modeled across three steps over 1 year. This procedure resulted in eight groups (see Staging Algorithm for Classifying Participants).

Objective Fitness Status

Height and weight were measured following standardized procedures by trained research staff at all three study waves. Participants wore light indoor clothing and were asked to take off their shoes. Height was measured to the nearest 0.1 cm using a wall-mounted stadiometer. Weight was measured using a digital scale (Omron Body Composition Monitor, BF511) to the nearest 0.1 kg. BMI was calculated as weight in kilograms divided by height in meters squared (kg/m^2).

Physical fitness was assessed at all three study waves by Physical Working Capacity (PWC) using a bicycle ergometer with pulse monitoring. The PCW refers to the physical performance of a person measured in watts at a specific heart rate (here: 130, i.e., PWC 130) divided by body weight (W/kg). The higher the PWC, the better a person's physical fitness.

Outcome Expectancies (OE) and Fulfillment of OE

Eight items were used to capture OE, based on the assessment in the Berlin Risk Appraisal and Health Motivation Study (cf. Schwarzer and Renner, 2000). Four items measured proximal OE (Cronbach's $\alpha = 0.87$), focusing on emotional outcomes very closely connected with the behavior, and another four measured distal OE (Cronbach's $\alpha = 0.81$), focusing on long-term gains such as health and social recognition. The eight specific items used were "If I am active on a regular basis, then…" (1) *I feel more balanced*, (2) *I feel better physically*, (3) *I feel more attractive*,

(4) *I feel more powerful*, (5) *it is good for my health*, (6) *my family and friends like it*, (7) *others appreciate my willpower*, (8) *I am a good example for others*. Items 1–4 are for proximal OE, items 5–8 are for distal OE. Answers were given on a four-point Likert scale ranging from 1, *not at all* to 4, *absolutely true*. Scale mean scores were calculated.

The following introduction preceded the assessment of OE fulfillment: "Please select from the following list the three most important positive consequences that you personally had expected from being physically active. Afterwards please assess whether your expectations concerning these selected consequences did fulfill." The item stem was "I had expected that if I am physically active, then…" followed by the same items as used in the OE measure. Participants selected the three expected outcomes that were most important to them by a tick box and rated the degree of fulfillment on a seven-point scale ranging from 1, 0%, 4, 50% to 7, 100% that appeared next to the statements. The mean of these three ratings was calculated to serve as the fulfillment score.

Action Self-efficacy

Five items were used to measure self-efficacy (Cronbach's $\alpha = 0.84$). These were based on items developed by Schwarzer and Renner (2000) as well as Scholz et al. (2005). The general question "How certain are you that you could overcome the following barriers?" was followed by specific items (e.g., "I can manage to be active on a regular basis, even if I have to rethink my entire way of physical activity"). A four-point response format ranging from 1, very uncertain to 4, very certain was used.

Data Analysis

SPSS Version 21.0 statistics software was used for data analysis. Less than 1% of the values were missing, with less than 0.5% missing after scale computation. Two multivariate outliers were identified. Since results omitting those did not differ from the complete sample analysis, the results of the latter are reported below.

Discriminant function analysis was used to identify differences between groups with characteristic trajectories of physical activity. Linear combinations of discriminant coefficients for simultaneously analyzed dependent variables (DV) are estimated as discriminant functions maximizing group differentiation. The chi-square test based on Wilk's Lambda indicates whether a function significantly discriminates between groups. Also, classification percentage can be used to assess the quality of analysis. Press's Q-value (Chan, 2005) indicates whether the discriminant functions assign cases to groups better than chance. The influence of each DV on the differentiation of groups can in turn be assessed by the standardized discriminant coefficients that are interpreted similarly to standardized regression coefficients (β). Thus, the importance of DV can be estimated for each single discriminant function. The mean influence ($\bar{\beta}$) of one DV over all functions is calculated by weighing the DV's standardized discriminant coefficient in each function with the function's eigen-value and dividing it by the number of functions considered (Tabachnick and Fidell, 2001).

A sequential technique (Tabachnick and Fidell, 2001) to test alternative models of varying complexity was used. Given our assumption that fulfillment of OE was the most influential variable for the discrimination between groups with successful vs. unsuccessful activity development, OE fulfillment was included first. Consecutively, proximal OE, action self-efficacy, and distal OE were included—first, one by one, then in different combinations—to test (via Chi-square comparison of Press's Q-values) whether they further improved group differentiation.

RESULTS

Distinct Physical Activity Trajectories Over 1 Year

Staging Algorithm for Classifying Participants

By combining the answers to the two Wave 2 questions asking after participants' physical activity level, all participants that reported attempts to become more physically active were assigned to one of four basic characteristic activity trajectory groups: *persistent actors* (had been active at Wave 1 and had successfully increased their activity level at Wave 2), *insistent actors* (had been active at Wave 1 but did not succeed in further increasing their activity level at Wave 2), *progressive intenders* (had not been active at Wave 1 but succeeded in becoming more active at Wave 2), and *permanent intenders* (had not been active at Wave 1 and did not succeed in becoming more active at Wave 2).

These four groups could then be further differentiated according to their Wave 3 statement as either *successful*, having increased their activity level (again), or *unsuccessful*. This staging according to participants' reported trajectories of adoption and maintenance of physical activity finally resulted in eight distinct groups (**Table 1**).

Of the 341 (44% of total) participants that were classified at Wave 2, $n = 215$ participated at Wave 3; of whom $n = 138$ attempted to become more physically active. Comparing drop-outs ($n = 126$) to returnees ($n = 215$) among the classified participants, there were no differences regarding the study variables (all $F < 1.13$, $p > 0.05$), BMI, $F_{(1,203)} = 1.56$, $p = 0.77$, or sociodemographics (gender, years of education; both $F < 0.18$, $p > 0.05$) except for age, analogous to the main sample. Also, there was no selective drop-out of the different stage trajectories: 34.9% of *persistent actors*, 34.3% of *insistent actors*, 38.2% of *progressive intenders*, and 43.1% of *permanent intenders,* $\chi^2_{(3)} = 1.71$, $p = 0.63$. With a mean (*SD*) age of 42.3 (16.8) compared to 47.6 (16.6), drop-outs were younger than the remaining sample, $F_{(1,338)} = 8.07$, $p = 0.01$, $\eta^2 = 0.02$. Being representative of the whole sample, the 138 (60.1% female) participants of the activity trajectory groups ranged from 20 to 87 years of age, mean (*SD*) age was 47.8 (16.7), mean (*SD*) BMI was 25.4 (4.3), and years of education were 15.8 (2.3). The activity trajectory groups did not differ in baseline BMI or PWC scores, ranging from 23.78 (2.24) to 26.71 (5.00) and 1.93 (0.38) to 1.71 (0.39), respectively. There were no differences regarding age distributions across trajectory groups.

TABLE 1 | Study variables by activity groups.

Activity groups	n	Fulfillment of OE (Waves 2–3)		Proximal OE (Wave 2)		Distal OE (Wave 2)		Action self-efficacy (Wave 2)	
		M (SD)	Range	M (SD)	Range	M (SD)	Range	M (SD)	Range
Successful persistent actors (111)*	18	5.77 (0.76)	4.00–7.00	3.56 (0.55)	2.50–4.00	3.10 (0.68)	1.75–4.00	2.78 (0.51)	2.00–4.00
Unsuccessful persistent actors (112)	18	5.14 (1.13)	3.33–7.00	3.71 (0.46)	2.75–4.00	2.94 (0.58)	1.75–3.75	2.69 (0.42)	2.00–3.60
Successful insistent actors (121)	15	5.42 (0.86)	4.00–7.00	3.50 (0.43)	3.00–4.00	2.80 (0.71)	2.00–4.00	2.69 (0.52)	1.40–3.40
Unsuccessful insistent actors (122)	31	4.74 (1.00)	2.67–7.00	3.36 (0.66)	1.25–4.00	2.66 (0.63)	1.00–4.00	2.38 (0.54)	1.00–3.80
Successful progressive intenders (211)	14	5.45 (0.89)	4.00–7.00	3.54 (0.52)	2.50–4.00	2.91 (0.66)	2.00–4.00	2.61 (0.49)	1.80–3.40
Unsuccessful progressive intenders (212)	11	5.07 (0.89)	3.33–6.00	3.34 (0.63)	2.25–4.00	2.85 (0.58)	1.75–3.75	2.40 (0.46)	1.60–3.00
Successful permanent intenders (221)	15	5.12 (0.67)	4.00–6.67	3.45 (0.44)	3.00–4.00	2.53 (0.65)	1.50–4.00	2.39 (0.51)	1.80–3.60
Unsuccessful permanent intenders (222)	16	4.76 (0.82)	2.67–5.67	3.20 (0.56)	2.00–4.00	2.83 (0.78)	1.50–4.00	2.10 (0.63)	1.00–2.80

*OE, outcome expectancies; M, mean; SD, standard deviation.*For activity groups, numbers in parentheses reflect the options chosen for activity level at Waves 1, 2, and 3. The first number in parentheses reflects the option chosen for T1 with 1, had been active regularly before and 2, had tried to become active but did not finally succeed. The second and third number in parentheses reflect the option chosen at T2 and T3 with 1, became more physically active and 2, tried to become more physically active but did not succeed.*

Objective Validation of Activity Trajectory Groups

To validate the staging of the participants into eight groups with different activity trajectories, the change of PWC scores between Waves 2 and 3 was used as the objective criterion for the actual increase in physical fitness. Neither absolute scores nor change scores were associated with the age of the participants. Analysis of variance revealed a significant main effect for the change in physical fitness, $F_{(7,\ 79)} = 2.58$, $p = 0.02$, $\eta^2 = 0.19$. Planned contrasts showed that the groups reporting a successful increase in physical activity at Wave 3 indeed had, unlike unsuccessful groups, improved in terms of objective fitness, $F_{(1,\ 79)} = 5.93$, $p = 0.02$, $\eta^2 = 0.07$. Specifically, those with a *successful* increase in physical activity (see **Table 1**) had a mean (*SD*) increase of PWC from 1.78 (0.48) to 1.82 W/kg (0.40), while unsuccessful groups showed a decreased mean (*SD*) PWC from 1.80 (0.44) to 1.74 W/kg (0.48) from Wave 2 to Wave 3, respectively.

The most critical groups are those of permanent intenders who intended to change their activity behavior from Wave 1 onwards, but were unsuccessful until Wave 2. Whereas one subgroup finally succeeded in implementing activity at Wave 3, the other's efforts failed again. Contrasting these two groups of *successful* versus *unsuccessful permanent intenders* also revealed a significant difference in PWC change scores, $F_{(1,\ 79)} = 5.94$, $p = 0.02$, $\eta^2 = 0.07$. Those who were eventually successful showed a mean (*SD*) PWC increase from 1.73 (0.37) to 1.79 W/kg (0.34), whereas those who were continually unsuccessful showed a decreased mean (*SD*) PWC from 1.71 (0.39) to 1.55 W/kg (0.46), at Waves 2 and 3, respectively. Overall, the objective assessment of physical fitness via PWC confirmed the staging of participants, since all people classified as successful increased in physical fitness measured by PWC on the group level and all people classified as unsuccessful decreased in physical fitness on the group level. For the subgroup of *unsuccessful insistent actors* only, tendencies were not in the predicted direction. This, however, might be due to the fact that this group of people was consistently active throughout the study period despite their (not implemented) attempts to further increase activity levels.

Discriminating Successful Behavior Changes by Fulfillment of OE

Fulfillment of OE (Wave 3) showed small to medium correlations with action self-efficacy ($r = 0.36$, $p < 0.001$), proximal OE ($r = 0.13$, $p = 0.26$), and distal OE ($r = 0.30$, $p = 0.001$), all Wave 2. Action self-efficacy correlated with neither proximal OE ($r = 0.17$, $p = 0.06$) nor distal OE ($r = 0.05$, $p = 0.60$), all Wave 2.

Overall, older participants (60+ years of age) and middle aged participants (35–60 years of age) were only slightly, and non-significantly, more likely to be unsuccessful (56 vs. 57%) in their attempts to increase physical activity than younger adults (45%), $\chi^2_{(2)} = 3.84$, $p = 0.147$. Higher age was associated with somewhat less OE, $r = -0.15$, $p < 0.001$, and correspondingly less OE fulfillment, $r = -0.24$, $p < 0.001$. Action self-efficacy did not correlate with age.

Proximal OE concerning emotional rewards represent 79% of the OE that participants selected as personally most important. Thus, four out of five OE concerned hedonic gains closely related to the physical activity behavior itself. In terms of fulfillment, the most successful expectancies were feeling more balanced, mean (*SD*) = 5.32 (1.06), and gaining a higher physical well-being, mean (*SD*) = 5.30 (1.13).

First, we ran discriminant analysis using half year trajectories data (from Wave 1 to Wave 2; $n = 341$). Fulfillment of OE clearly discriminated the four groups (centroids in parenthesis) as being either successful, that is, *persistent actors* (0.45) and *progressive intenders* (0.28) or unsuccessful, that is, *insistent actors* (–0.25) and *permanent intenders* (–0.52), $\lambda = 0.86$, $\chi^2_{(3)} = 45.43$, $p < 0.001$, $\eta^2 = 0.78$ (classification rate = 41.2%; Press's Q-value = 43.88, $p < 0.001$).

Second, for trajectories throughout 1 year ($n = 138$) degree of OE fulfillment (model 1 of the sequential discriminant function analyses, see **Table 2**) significantly differentiated the eight activity groups, $p = 0.02$. Including proximal OE (model 2a), action self-efficacy (model 2b), or distal OE (model 2c) did not improve group discrimination. However, simultaneously including OE fulfillment with proximal OE and action self-efficacy significantly improved discrimination (model 3). This discriminant model, $\chi^2_{(1)} = 5.14$, $p < 0.05$, $\eta^2 = 0.86$, offered the best classification rate (31.9%), and with a Press's Q of 41.09, $p < 0.001$, qualified the classification as better than chance. The further addition of distal OE (model 4) did not improve classification, neither in contrast to model 1 (**Table 2**) nor in contrast to model 3, $\chi^2_{(1)} = 0.50$ (n.s.). The three discriminant functions of the final model (model 3) were interpreted (**Table 3**).

Taken together, all three functions significantly differentiated groups, $\lambda = 0.70$, $\chi^2_{(21)} = 40.25$, $p = 0.007$, $R^2 = 0.20$, but functions two and three, $\lambda = 0.88$, $\chi^2_{(12)} = 14.62$, $p = 0.26$, $R^2 = 0.11$, or function three alone, $\lambda = 0.99$, $\chi^2_{(5)} = 0.89$, $p = 0.97$, $R^2 = 0.01$, did not. The second function explained 33% extra variance not explained by the first function, but the third function did not substantially contribute to discrimination.

OE fulfillment ($\beta = 0.60$) was the predominant predictor of group differentiation in function 1, being the most meaningful function that explained the most variance. The groups *persistent actors* (group centroids 0.69 and 0.37 for those *successful* and those *unsuccessful* at Wave 3, respectively), *successful insistent actors* (centroid = 0.45), and *successful progressive intenders* (centroid = 0.40) were discriminated from *unsuccessful insistent actors* (centroid = −0.47) and *unsuccessful progressive intenders* (centroid = −0.26) as well as both groups of *permanent intenders* (centroids −0.10 and −0.78 for those finally *successful* and those still *unsuccessful* at Wave 3, respectively). Thus, the first function separates those most successful from those vastly unsuccessful. The latter subsample also includes those permanent intenders finally successful in increasing their physical activity level. Despite their eventual success, this group has a negative centroid, but it is the least negative. Arguably, this can be seen as a result of very recent success after being unsuccessful for the majority of the study period. Their increase in physical activity was probably more tentative than that of the four groups that had proven to be successful in the long run.

In function 2, the most influential factor was proximal OE ($\beta = 0.89$), discriminating *unsuccessful persistent* (centroid = 0.69) and *unsuccessful insistent actors* (centroid = 0.30) from all other groups. These groups could be described as those with the most serious relapses since both had a trajectory of successful increases of physical activity at the beginning of the study that was disrupted at Wave 3. **Figure 1** shows the differentiation of the eight activity groups by the two discriminant functions. Fulfillment of OE was the most important predictor ($\overline{\beta} = 0.60$) across both functions, followed by proximal OE ($\overline{\beta} = 0.45$) and action self-efficacy ($\overline{\beta} = 0.40$).

DISCUSSION

Using the longitudinal, real-life cohort sample from the Konstanz Life Study, this research indicates that the fulfillment of expectations about positive outcomes contributes significantly to successfully increasing physical activity. Groups with distinct activity trajectories were compiled using a staging algorithm based on self-reported activity levels and attempts to change behavior reported over 1 year. These groups were validated via objective fitness data. Participants who reported successful increases in physical activity indeed showed improved PWC, unlike those who did not succeed in implementing their good intentions. Activity group membership could be predicted by the reported degree of fulfillment for the three most important OE. These predominantly concerned hedonic rewards directly related to being physically active. Proximal, that is, emotional OE and self-efficacy further improved the discriminatory power to classify successful versus unsuccessful actors.

Fulfilled OE Mean Positive Feedback Loops

Whether people report on successful increases of their activity levels seems to depend on whether their positive expectations have been met. This fits with Fuchs' (2013) and Rothman's (2000) suggestions that positive experiences are important for long-term adherence to physical activity. Obviously, if people do not get what they expected, value of the behavior is

TABLE 3 | Discriminant functions including fulfillment of OE, proximal OE, and action self-efficacy to differentiate activity groups.

Function	Standardized canonical discriminant coefficients (β)			Variance explained %	Canonical R^2
	Fulfillment of OE	Proximal OE	Action self-efficacy		
1	0.60	0.24	0.56	65.0	0.20
2	−0.65	0.89	0.11	33.0	0.11
3	0.56	0.48	−0.88	2.0	0.01

OE, outcome expectancies.

TABLE 2 | Sequential discriminant functions for activity groups.

Model	Predictors	Wilk's Lambda	Classification rate %	Improvement of prediction over model 1
1	Fulfillment of OE	0.85	26.1	–
2a	Fulfillment of OE, proximal OE	0.75	29.4	$\chi^2_{(1)} = 2.25$, n.s.
2b	Fulfillment of OE, action self-efficacy	0.77	28.6	$\chi^2_{(1)} = 1.33$, n.s.
2c	Fulfillment of OE, distal OE	0.79	27.7	$\chi^2_{(1)} = 0.05$, n.s.
3	Fulfillment of OE, proximal OE, action self-efficacy	0.70	31.9	$\chi^2_{(1)} = 5.14$, $p < 0.05$
4	Fulfillment of OE, proximal OE, action self-efficacy, distal OE	0.64	30.3	$\chi^2_{(1)} = 3.20$, n.s.

Improvement of prediction was assessed using Press's Q-values, tested with the Chi-square test. OE, outcome expectancies.

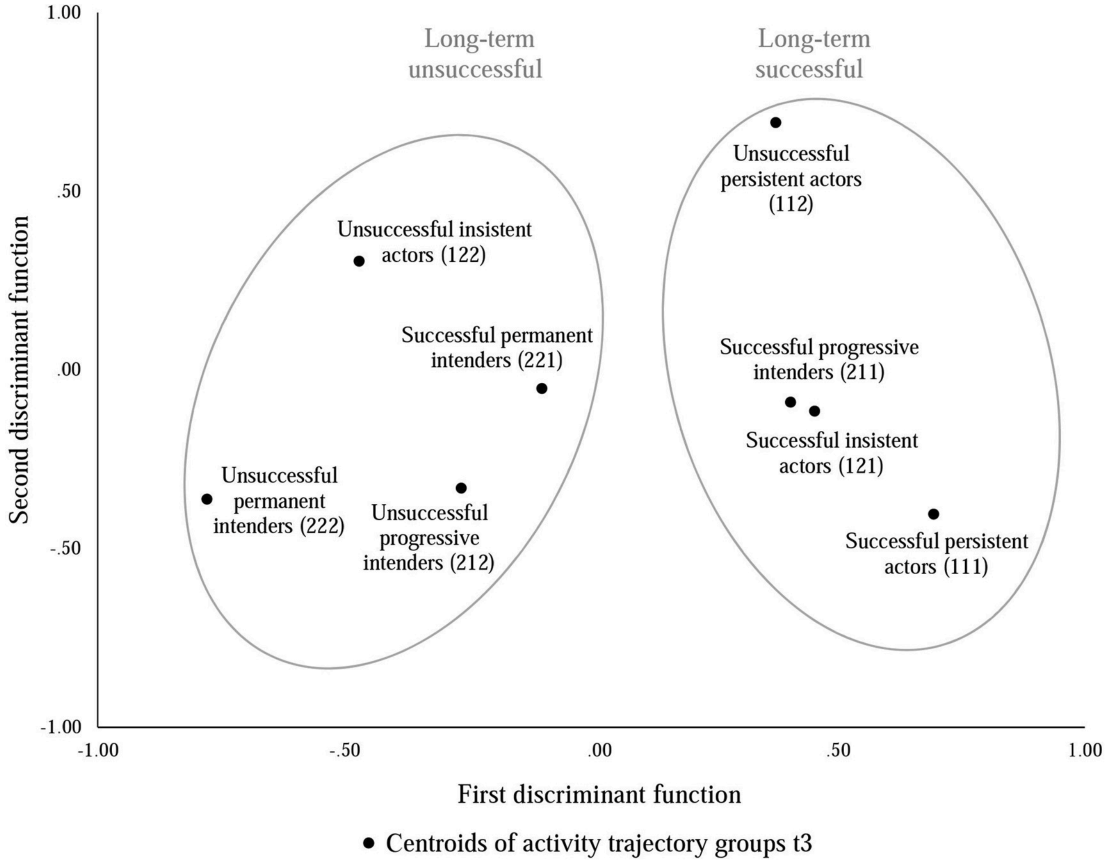

FIGURE 1 | Differentiation of activity groups according to first and second discriminant function. The centroids of activity groups represent the mean scores of the groups on both discriminant functions that are composed of the weighed predictors according to the equations of the two discriminant functions. Ellipses surrounding centroids represent group differentiation by the first discriminant function. The long-term unsuccessful ellipse also includes successful permanent intenders. This might result from the very recent success of this group after being unsuccessful for the majority of the study period.

reduced and disengagement from behavior change becomes more likely. This regulation process seems by far the most logical given competing goals and limited resources, such as time investment and mental as well as physical effort. Fulfilled outcome expectancies, in contrast, reward efforts made and subsequently reinforce behavior value and thus behavior change. In a study on ceasing smoking, Baldwin and colleagues (2006) found that satisfaction with the outcomes of having quit predicted whether people maintained non-smoking status. These cycles could be visualized as positive feedback loops where hedonic rewards—since the most relevant expectations are those about proximal emotional outcomes—feed-back on good intentions that in turn reinforce activity behavior. Thus, coming from the outcomes in the volitional phase, calibration of expectancies is important for future motivational processes.

A Closer Look at the Dynamics of OE in Health Behavior Models

Our study has implications for behavior change models since the fulfillment of OE was shown to be a distinct predictor that only correlates with the established social-cognitive variables OE and self-efficacy to a medium extent. Thus, future models could include expectation fulfillment to maximize power when predicting behavior change. Also, more intense data acquisition, like ecological momentary or ambulatory assessment (see Renner et al., 2015), could further help to clarify the dynamic of individual expectations and their fulfillment. Including an objective measurement of activity behavior using accelerometry, for example, would allow for an "on-line", in-depth investigation of the interplay of OE fulfillment and actual behavior while behavior changes occur.

Our measure addressed classical domains of OE that provide the value of physical activity, being proximal affective incentives versus more distal social or health benefits (see Steinhardt and Dishman, 1989; Hallam and Petosa, 2004; Schwarzer, 2008a; Gellert et al., 2012). In analyzing the data on the three most important OE, it became evident that people had almost exclusively chosen proximal OE. This preference is advantageous given that these expectancies of positive emotional outcomes helped predict successful activity increase. Similarly, Conner and colleagues (2011) found that information on the affective outcomes of activity was more effective in increasing activity than health-related information. It seems logical that proximal OE optimally support behavior change since they are less prone to interference and are more likely to occur than distal ones. Emotional rewards directly supply hedonic needs and thus act as a driving force for behavior change maintenance. In contrast, distal outcomes like social recognition depend on the reaction of relevant others, over which the agent has little control, and whether health gains are reached is only resolved in the long run. Based on our findings, a more subtle segmenting of OE, which exceeds the dimensions of proximal and distal OE, and possibly also a detachment of expectancy (including expected likelihood of occurrence) and value could be addressed in future studies. Similarly, recent work in the physical activity domain suggested focusing on affective determinants of behavior (Rhodes et al., 2009; Jekauc et al., 2015) and systematizing different dimensions of OE (French et al., 2005; Conner et al., 2011; Gellert et al., 2012).

Focusing on OE Fulfillment in Interventions

Interventions to increase physical activity have well-established the concept of action planning and coping planning (Leventhal et al., 1965; Scholz et al., 2008; Schwarzer, 2008a). In parallel to these well-established approaches to help people overcome barriers, another independent social-cognitive pathway to health behavior via satisfaction was suggested (Fleig et al., 2011). Recently, Conner and colleagues (2015) claimed studies manipulating affective attitudes and anticipated affective reactions. Extending interventions to foster realistic OE might help overcome problems of low long-term increases in physical activity (Evers et al., 2012; Renner et al., 2012a). Before becoming active, people often underestimate enjoyment because they focus on the unpleasant and aversive beginning (Ruby et al., 2011). Consequently, expectancy adjustment might help people focus on accomplishable, preferably proximal, outcomes. Also, enabling people to perceive attained positive outcomes would provide additional benefit, thereby reinforcing behavior change and ensuring behavior change maintenance. A recent proof of principle study showed that instructing exercise trainers using strategies to promote positive emotions was effective in evoking positive affective states during exercise and increasing adherence (Jekauc, 2015). Similarly, affective short-term messages produced the highest levels of physical activity in a large student sample (Morris et al., 2015). If people focus on long-term health effects or social reputation instead, they are prone to disregard emotional benefits that seem a necessary incentive for successful increases in physical activity.

Limitations

The main limitation of our study concerns the small cell sizes that resulted from sorting people into groups with specific activity trajectories using the staging algorithm. However, the subgroups do represent the different age groups accurately and are comparable to the demographics and socio-economic status of the main sample, which was taken from a real-life cohort study. The theory-based, in-depth perspective of our data allows surveying tangible behavior change trajectories and is a major strength of our study which was undertaken in a naturalistic non-intervention setting. Still, the small number of people who are physically active or intending to become so is alarming. Like common staging procedures, we used a rating scale with verbal anchors (e.g., Sutton, 2005; Lippke et al., 2009). Although stages were validated by objective physical fitness, the subjective reasoning of behavior change is the decisive venue of social-cognitive dynamics. This is why we asked about general attempts to be "physically active regularly" without further confinement (e.g., objective recommendations for physical activity; see Haskell et al., 2007). Providing distinct goal criteria for the amount of physical activity would restrict the room for subjective goal setting. Our findings should be replicated in future studies, preferably also in health promotion programs and intervention studies that have a different respondent structure by design.

A further critique might include that the study focused on people who were already active (actors) or who had attempted to change their activity behavior ("attempters"). These numbers are comparable to similar longitudinal health screening studies (Prochaska et al., 1985; Lippke et al., 2004, 2005, 2009). As noted above, however, this also meant excluding roughly half of the participants (56%). Additional strategies are necessary to address individuals who have not thought about beginning physical activity and those who have thought about changing their behavior but not formed an intention, pre-intenders or (pre-)contemplators. To begin with the classical motivational parameters of risk information, notifying people about outcomes, and fostering self-efficacy might now, in the light of our findings, also include the promotion of outcomes with high chances of fulfillment, that is, affective rewards or emotional benefits.

Finally, we found that older participants were somewhat less successful in increasing physical activity despite actual attempts. Decreased OE and the subsequently lower OE fulfillment across age underscore that older adults are an especially critical group that needs special attention in future research and intervention design. Possibly, a maladapted profile of OE regarding physical activity in old age might contribute to the low physical activity rates in old age (Krug et al., 2013). Older people might also hold stronger negative OE and face increased physical barriers to activity than younger adults (Fuchs, 1994; Toscos et al., 2011). There is an ongoing debate on the role of negative OE (Williams et al., 2005; Schwarzer, 2008a; Conner et al., 2015). The present study focused on positive OE because spontaneous elicitation of OE resulted in more positive OE (Rhodes and Conner, 2010), and recent studies indicated that positive OE might be more important to fostering health behavior change (Aaltonen et al., 2012; Basen-Engquist et al., 2013). However, expected negative outcomes have also been found to be negatively related to health behavior changes (Williams et al., 2005; Hankonen et al., 2013; Gyurcsik et al., 2015) and might be investigated in future studies as a cause of sedentary behavior, especially in specific target groups. In line with the results on the importance of proximal, emotional OE fulfillment in our study here, we previously demonstrated that exercise in old age can indeed increase perceived emotional gains and mastery experiences derived from being physically active. This mechanism could even explain why exercise buffers aging dissatisfaction in older women (Klusmann et al., 2012). Addressing age-specificity in health behavior change dynamics seems an important issue for future studies. The development of new approaches for effective expectancy modification must cope with target-group specific dispositions.

Conclusions

It seems that the success of sustainable behavior change depends on whether people obtain what they expect. Ascertaining whether and in how far expectations about the consequences of physical activity have been met contributes to the accurate prediction of whether people are on the road to success or doomed to failure. That the fulfillment of emotional outcome expectancies emerges as a significant predictor in addition to traditional means, namely established motivational variables, has important implications for both health behavior change modeling and intervention design.

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Physical Activity Enjoyment and Self-Efficacy As Predictors of Cancer Patients' Physical Activity Level

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Background: Physical activity (PA) can support cancer patients during medical treatment by reducing side-effects and increasing quality of life. However, PA levels mostly decline after diagnosis. Which factors can explain if patients are able to remain or even increase their PA level? Self-efficacy is an important cognitive factor that has been linked to cancer patients' PA across many studies. In contrast, affective factors such as PA enjoyment have rarely been examined. We compare the influence of self-efficacy and PA enjoyment on cancer patients' PA levels after completion of an exercise or stress-management intervention.

Methods: Outpatient cancer patients [$N = 72$; 54% female; $M = 56$ years, $SD = 12.34$; most with breast or colon cancer (34%, 15%)] were enrolled in the MOTIVACTION study, a 4-week intervention (1 h counseling followed by weekly phone calls), with pre-test (T1), post-test (T2), and a 10-week follow-up (T3). Participants were randomized to either an exercise intervention (emphasizing self-regulatory strategies for behavior change) or to a stress management intervention (coping and relaxation techniques). Sixty-seven patients remained in the study and completed the SQUASH assessment of PA, a measure of maintenance self-efficacy (7 items, Cronbach's $\alpha = 0.88$) and PA enjoyment (2 items, Cronbach's $\alpha = 0.89$). Regression analyses were calculated with PA level (at T2 and T3) as dependent variable and relative weight analyses were conducted. The study was registered at clinicalTrials.gov (unique identifier:NCT01576107; URL: https://clinicaltrials.gov/ct2/show/NCT01576107?term=motivaction&rank=1).

Results: Baseline self-efficacy and change in PA enjoyment significantly predicted cancer patients' PA level at T2 adjusting for baseline PA and type of intervention. Relative weight (RW) analysis revealed that PA enjoyment (baseline and change together) explained 34.3% of the dependent variable, self-efficacy (baseline and change) explained 38.4%. At follow-up, self-efficacy was still a significant predictor of PA (RW = 74.6%), whereas PA enjoyment was no longer a relevant factor (RW = 5.2%).

Conclusion: The affective factor PA enjoyment was equally important as self-efficacy for predicting cancer patient' PA level directly after completion of the intervention. Reasons for the reduced relevance at follow-up and a broader range of affective factors should be analyzed in future studies on cancer patients' PA level.

Keywords: physical activity enjoyment, self-efficacy, physical activity, cancer, affective factors, cognitive factors, intervention

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INTRODUCTION

Regular physical activity (PA) has various beneficial effects for cancer patients both during and after medical treatment (Speck et al., 2010; Fong et al., 2012; Jones and Alfano, 2012). Current reviews and meta-analyses demonstrate, for example, positive effects on health-related quality of life (Mishra et al., 2012), cancer-related fatigue (Cramp and Byron-Daniel, 2012), depression (Craft et al., 2012), aerobic fitness (Jones et al., 2011), and muscle strength (Stene et al., 2013; Strasser et al., 2013). Cancer patients are recommended to engage in 150 min per week of at least moderate PA (Schmitz et al., 2010). However, it has been shown that only a minority of cancer patients meet these guidelines (Blanchard et al., 2008).

Various social cognitive theories—such as the Theory of Planned Behavior (TPB; Ajzen, 1991), the Social Cognitive Theory (SCT; Bandura, 1977, 1986), the Transtheoretical Model (Prochaska and DiClemente, 1983) or the Health Action Process Approach (Schwarzer, 2008)—try to explain why people do (not) engage in a health behavior such as PA. The TPB and the SCT have most frequently been applied to explain the low PA level of cancer patients (see Pinto and Ciccolo, 2011 for an overview). Self-efficacy is a core component of many social cognitive theories. As cancer patients face not only general barriers regarding PA such as bad weather, but also treatment related barriers such as fatigue (Brawley et al., 2002; Midtgaard et al., 2009; Blaney et al., 2013), self-efficacy is especially necessary in the oncological context to overcome these specific barriers. Self-efficacy turned out to be the best predictor of behavioral intention in most TPB studies in the field of PA and cancer (e.g., Karvinen et al., 2007; Keats et al., 2007; Speed-Andrews et al., 2012; Trinh et al., 2012) and often has an independent effect on PA behavior besides intention (e.g., Karvinen et al., 2007; Keats et al., 2007; Trinh et al., 2012). For example, there were moderate associations ($r = 0.69/r = 0.43$) between perceived behavioral control (similar to self-efficacy) and PA level/ intention in a cross-sectional study of 600 colorectal cancer survivors (Speed-Andrews et al., 2012). Similarly, in studies applying the SCT, self-efficacy is consistently identified as a psychosocial determinant of PA among cancer patients (e.g., Phillips and McAuley, 2013; Rogers et al., 2004). A meta-analysis by Stacey et al. (2015) summarizes behavior change studies using the SCT. It included twelve studies applying PA interventions based on the SCT to oncological patients. The meta-analysis found a significant intervention effect for increased PA levels (standardized mean difference = 0.33). Improvements in self-efficacy were in some studies associated with a following increase in PA (Pinto et al., 2005; Demark-Wahnefried et al., 2007; von Gruenigen et al., 2008; Ligibel et al., 2012).

Common theories of health behavior such as the TPB focus on cognitive constructs and do not explicitly incorporate affective factors, which can lead to a limited predictive power of these theories (McEachan et al., 2011; Conner et al., 2015). Current research tries to reduce this gap by including affective factors (Williams and Evans, 2014). PA enjoyment is one prominent and frequently applied affective component (see reviews by Rhodes et al., 2010; Nasuti and Rhodes, 2013) capturing experience and expectation of pleasure toward PA (Williams and Evans, 2014; Lewis et al., 2016).

In the context of cancer research, affective factors are very important, as many patients often experience psychological and emotional distress as well as depressive symptoms (Knobf, 2007; Jayadevappa et al., 2012; Jones et al., 2015). To deal with the disease many patients use various self-management strategies, whereby PA is the most commonly used one (Shneerson et al., 2015). Thereby, feeling self-determined regarding PA can increase positive affect (Brunet et al., 2013) and being passionate about activities positively affects emotional well-being (Burke et al., 2012).

Up to now, only a few studies have included PA enjoyment to predict cancer patients' PA level (e.g., Rogers et al., 2008, 2011; Charlier et al., 2013). PA enjoyment was mostly assessed with a one item measure (e.g., 2015; Rogers et al., 2011). Within these mostly correlational studies, PA enjoyment was always one of the strongest determinants of PA (Rogers et al., 2008; Charlier et al., 2013). For example, in a correlational study among head and neck cancer patients, task self-efficacy ($r = 0.33$), perceived barriers ($r = -0.27$), and PA enjoyment ($r = 0.41$) were the strongest correlates of PA (Rogers et al., 2008). In another cross-sectional study among 464 breast cancer survivors, PA enjoyment significantly explained leisure time PA ($\beta = 0.2$), but did not influence other domains of PA such as household or transportation (Charlier et al., 2013).

As self-efficacy as well as PA enjoyment have shown to be associated with PA, an important issue is the relative importance of affective factors compared to cognitive factors in explaining and predicting PA. This was the focus of a recent longitudinal study with healthy adults (mainly women), which investigated the relative importance and interrelationships between self-efficacy and PA enjoyment in predicting the initiation and maintenance of PA (Lewis et al., 2016). It turned out that PA enjoyment was a more powerful predictor for PA at a 12-month follow-up than self-efficacy. To explain this result, the authors tested several mediation models and found that PA enjoyment exerted its effects on PA levels through self-efficacy. Among people with a chronic disease such as cancer, the relative importance of self-efficacy and PA enjoyment has—to our knowledge—not been investigated so far.

If self-efficacy and PA enjoyment can lead to an increased PA level, improvements in these variables are likely to result in continued PA adherence (Morielli et al., 2016). Thus, it would be favorable if these two factors could be increased through an intervention as well. With respect to self-efficacy, Bandura's theory postulates four sources: mastery experience, vicarious experience, verbal persuasion and emotional arousal (Bandura, 1977, 2000). In a successful PA promotion intervention, a participant should experience mastery through feeling able to perform more PA now. The other three sources could be addressed in an intervention as well (e.g., vicarious experience through contact with a role model). In contrast to self-efficacy which is a "classic" and often studied cognitive construct, the affective construct PA enjoyment was introduced more recently and—at least to our knowledge—no theoretical assumptions have been formulated yet which factors should lead to an increase. However, first two pilot studies found improvements in PA enjoyment by a PA intervention (Rogers et al., 2011; Morielli et al., 2016). This leads to the question if PA enjoyment can be increased through a PA promotion intervention and which psychological, medical and sociodemograhpic variables are related to a change in PA enjoyment.

In the current study, we want to compare the influence of self-efficacy and PA enjoyment on cancer patients' PA level after completion of an exercise or stress-management intervention. The main objective is to investigate if the affective variable PA enjoyment predicts the PA level of cancer patients (at T2 and T3) over and above the cognitive variable self-efficacy (research question 1). Furthermore, we were interested to explore whether self-efficacy and PA enjoyment increased during the interventions (research question 2). Finally, additional analysis examine exploratively which factors are associated with changes in PA enjoyment.

METHODS

Design

The MOTIVACTION (MOTivational InterVention enhancing physical ACTivity In ONcology patients) study consisted of two interventions (exercise and stress management) and assessments at baseline (T1), 4 weeks after the intervention (T2), and 10 weeks after T2 (T3). Patients were randomized to one of the two groups by being stratified by sex, age (i.e., $<$ or $\geq$ 60 years), metastases (i.e., yes/no), and current chemotherapy (i.e., yes/no). The study protocol was approved by the ethic committee of the medical faculty in Heidelberg, Germany. All subjects gave written informed consent in accordance with the Declaration of Helsinki. The study was registered at clinicalTrials.gov (unique identifier: NCT01576107; URL: https://clinicaltrials.gov/ct2/show/NCT01576107?term=motivaction&rank=1).

Participants

Patients of any cancer entity meeting the following inclusion criteria were eligible to participate in the study: receiving out-patient therapy (acute or maintenance therapy) or finished this therapy not longer than 6 months ago, being $\geq$ 18 years, being below the current guidelines to be moderate active at least for 150 min per week, and being able to follow the study instructions. Exclusion criteria were: planned rehabilitation or inpatient treatment during the next 8 weeks, wound healing not completed, bone metastases, and serious comorbidities or comorbidity-related limitations.

Procedure

Participants were recruited at the National Center for Tumor Diseases in Heidelberg (Germany). In an initial (telephonic) meeting participants were screened if inclusion or exclusion criteria apply. Among others, patients were asked to rate their PA behavior in minutes during the last week. If the patients were less active than 150/min per week they were categorized as insufficiently active and could be enrolled in the study (if no other exclusion criteria occurred). After signing written informed consent participants were randomized either into the exercise or stress management group and received the baseline questionnaires. Both the exercise as well as the stress management intervention started immediately after returning baseline materials and consisted of an individual 1-h-counseling session, followed by three weekly telephone calls.

Interventions

The exercise intervention included counseling based on the Health Action Process Approach (Schwarzer, 2008). Patients received a booklet with behavior-change techniques (e.g., action planning, coping planning) and various exercises for home-based training, exercise materials (e.g., stretch band for resistance training) as well as a diary to record exercise sessions. The stress management intervention consisted of relaxation techniques such as abdominal breathing, progressive muscle relaxation and cognitive coping techniques (Jacobsen et al., 2013). Patients received a booklet with stress management techniques, a CD with relaxation techniques as well as a diary to record stress management sessions. The procedure and content of the two interventions are described in detail in Ungar et al. (2016).

Measures

PA enjoyment was assessed with two items based on Rogers et al. (2011, 2015). The two items were "I enjoy being regularly physically active" and "It is fun to engage in sport activities and regular PA". A response scale from 1 ("not at all") to 4 ("totally agree") was used and a mean was calculated from the two items. Cronbach's alpha was good ($\alpha = 0.89$).

Maintenance self-efficacy was assessed according to guidelines of the Health Action Process Approach (Schwarzer et al., 2003; Schwarzer, 2008). Seven items were used measuring the confidence with sticking to regular PA. An example item was "I am confident that I can permanently be regularly physically active even if I have side-effects (e.g., nausea) of the cancer-therapy" with a response format from 1 "not at all" to 4 "totally agree". The internal consisty was good (Cronbach's $\alpha = 0.88$) and a mean was used to aggregate the seven items.

Physical activity was measured using the slightly modified Short QUestionnaire to ASsess Health-enhancing physical activity (SQUASH) having good psychometric properties (Wendel-Vos et al., 2003; Wagenmakers et al., 2008).

The slightly modified questionnaire contained questions about physical activities related to commuting, household, leisure-time, and work. Every activity referred to the last 7 days and included three questions: days per week, average time per day and intensity (light, moderate, or vigorous). As the intervention focused on exercise behavior and not PA in general, we generated the variable "intended physical activity level" (iPAL). We classified the activities according to Caspersen et al. (1985) as exercise is "physical activity that is planned, structured, repetitive, and purposive in the sense that improvement or maintenance of one or more components of physical fitness is an objective" (p.128). iPAL therefore included all items of the domain leisure-time activities except gardening and odd work if participants reported an at least moderate intensity. These six items were: brisk (Nordic-) walking, bicycling, gymnastic or resistance training and three open-ended items called "sport activities." The open-ended responses were excluded from analysis if the indicated activity was below a metabolic equivalent of 4 according to the Ainsworth compendium (Ainsworth et al., 2011).

Data Analysis

Change scores of self-efficacy and PA enjoyment where calculated by subtracting the respective T2 scores from the T1 scores (T2 minus T1). Descriptive statistics and bivariate Pearson correlations were conducted. Drop-out analyses were calculated to compare completers versus non-completers of the intervention using *t*-tests for metric and Chi-squared tests for nominal variables. The first research question was analyzed using linear regression models and relative weight analysis. Relative weight analysis estimates the relative importance of correlated determinants in a regression equation by using a new set of uncorrelated determinants that are maximally related to the original set of correlated determinants (Tonidandel et al., 2009). A relative weight is the amount of variance explained by a single determinant; all relative weights add up to 100%. For the second research questions, analyses of variances (ANOVAs) for repeated measures [between subject factor: type of intervention (exercise/stress); within subject factor: time (T1/T2/T3)] were computed with self-efficacy and PA enjoyment as dependent variables. Additional analyses were calculated using regression analysis explaining the dependent variable $\Delta_{T1\text{-}T2}$PA enjoyment.

Listwise deletion was used if necessary in all analyses, as there were only less than 2% of data missing. Analyses were carried out with IBM SPSS Statistics 22 IBM corp. NY, USA, and employed a significance level of $p < 0.05$.

TABLE 1 | Baseline characteristics of the sample (N = 67).

	M	(*SD*)	*N*	(%)
Age in years	55.45	12.62		
Female			35	52.2
Family-status				
Relationship			55	82.1
Single			6	9.0
Separated			6	9.0
Education level[a]				
Low			13	19.4
Middle			17	25.4
High			37	55.2
Occupation				
Full-time			13	19.4
Part-time			8	11.9
No occupation			46	68.7
Cancer entity				
Breast			22	32.8
Colorectal			8	11.9
Prostate			5	7.5
Others			27	43.5
Existance of metastases			22	32.8
Chemotherapy				
Currently			25	37.3
Completed			16	23.9
Radiotherapy				
Currently			10	14.9
Completed			14	20.9
Treatment at NCT			42	62.7

[a] *low: ≤ 9 years; middle: 10 years; high: 12 years or more.*

RESULTS

Sample and Descriptives

The sample consisted of 72 cancer patients who were insufficiently active, that is not meeting guidelines of at least 150 min/week moderate PA at T1 (M = 47.22 min). They were randomized to the exercise intervention (n = 36) or to the stress management group (n = 36), with 67 completing the study (3 died, 2 drop-outs; details about the study flow can be found in Ungar et al., 2016). Participants were 52% female with a mean age of M = 55.45 years (SD = 12.62, range: 26–83 years). The majority had breast (33%), colorectal (12%), or prostate cancer (8%) with 33% having metastases and 37% having currently chemo-therapy (see **Table 1**).

Baseline Values in iPAL, Self-Efficacy and PA Enjoyment

Descriptive results and bivariate correlations are shown in **Tables 2, 3**. The correlation between PA enjoyment and self-efficacy was moderate (r = 0.372, p = 0.003) at baseline. Mean values of iPAL (M_{exercise} = 52.14, SD = 101.95; $M_{\text{stress-management}}$ = 41.84, SD = 92.47), PA enjoyment (M_{exercise} = 2.89, SD = 0.74; $M_{\text{stress-management}}$ = 2.84, SD = 0.81), and self-efficacy (M_{exercise} = 2.61, SD = 0.50; $M_{\text{stress-management}}$ = 2.59, SD = 0.59) did not differ significantly between the exercise intervention and the stress-management group before the start of the intervention (T1) ($p > 0.05$).

Research Question 1: Prediction of iPAL by PA Enjoyment and self-efficacy

As was described in Ungar et al. (2016), iPAL increased from T1 to T2 and T3 in both intervention groups (exercise group: M_{T1} = 52.14, SD_{T1} = 101.95; M_{T2} = 150.43, SD_{T2} = 161.13; M_{T3} = 189.43, SD_{T3} = 243.14; stress-management group: M_{T1} = 41.84, SD_{T1} = 92.47; M_{T2} = 69.06, SD_{T2} = 121.10; M_{T3} = 120.00, SD_{T3} = 193.38). The first hierarchical regression analysis predicting iPAL at T2 could explain 22.8% of variance in the first step (including type of intervention, iPAL at T1, self-efficacy at T1 and $\Delta_{T1\text{-}T2}$ self-efficacy as independent variables) and further 5% in the second step (including additionally PA enjoyment at T1 and $\Delta_{T1\text{-}T2}$PA enjoyment). Self-efficacy (at T1 and $\Delta_{T1\text{-}T2}$) was a positive significant predictor, and $\Delta_{T1\text{-}T2}$PA enjoyment could predict iPAL at T2 over and above this cognitive influence (β = 0.32). Relative weight analysis revealed that self-efficacy and PA enjoyment were of about equal importance in predicting iPAL at T2 (see **Table 4** for detailed statistics).

TABLE 2 | Descriptive statistics of study variables for the two intervention groups and for the whole sample.

		Exercise		Stress-management		Total	
		M	(*SD*)	*M*	(*SD*)	*M*	(*SD*)
Intended physical	iPAL T1	52.14	101.95	41.84	92.47	47.22	96.94
Activity level (iPAL)[a]	iPAL T2	150.43	161.13	69.06	121.10	111.57	148.12
	iPAL T3	189.43	243.14	120.00	193.38	156.27	221.90
PA enjoyment[b]	PA enjoyment T1	2.89	0.74	2.84	0.81	2.87	0.77
	PA enjoyment T2	3.23	0.73	3.22	0.66	3.22	0.69
	PA enjoyment T3	3.15	0.87	3.22	0.73	3.18	0.80
Self-efficacy[b]	Self-efficacy T1	2.61	0.50	2.59	0.59	2.60	0.54
	Self-efficacy T2	2.75	0.56	2.74	0.61	2.74	0.58
	Self-efficacy T3	2.73	0.60	2.79	0.58	2.76	0.59
Change-scores	ΔiPAL T1-T2	98.29	201.14	27.22	118.60	64.35	169.49
	ΔiPAL T1-T3	137.29	249.60	78.16	194.63	109.05	225.33
	ΔiPAL T2-T3	39.00	228.11	50.94	203.97	44.70	215.36
	ΔPA enjoyment T1-T2	0.34	0.79	0.38	0.43	0.35	0.64
	ΔPA enjoyment T1-T3	0.26	0.97	0.36	0.82	0.31	0.90
	ΔPA enjoyment T2-T3	−0.08	0.74	0.00	0.74	0.04	0.73
	Δself-ef icacy T1-T2	0.14	0.56	0.15	0.62	0.14	0.58
	Δself-ef icacy T1-T3	0.12	0.66	0.20	0.40	0.16	0.55
	Δself-ef icacy T2-T3	−0.02	0.57	0.05	0.58	0.02	0.57

[a] *In minutes per week (practiced during the last week);*
[b] *On a scale from 1 to 4.*

The second hierarchical regression analysis predicting iPAL at T3 revealed a differing finding. In the first step (including type of intervention, iPAL at T1, self-efficacy at T1 and $\Delta_{\text{T1-T2}}$ self-efficacy as independent variables) 16.4% of variance could be explained and only self-efficacy at T1 had a significant effect ($\beta = 0.457$, $t = 3.305$, $p = 0.002$). In the second step, PA enjoyment (at T1 as well as $\Delta_{\text{T1-T2}}$) did not add any variance and was no significant predictor (see **Table 4**).

Research Question 2: Changes in Self-Efficacy and PA Enjoyment

Two ANOVAS with repeated measures showed that both PA enjoyment [$F_{(2,\ 116)} = 7.317$, $p = 0.001$] and also marginally self-efficacy [$F_{(2,\ 126)} = 2.690$, $p = 0.072$] increased across the three measurement points (see **Table 2**). Looking at the effect sizes, the increase of PA enjoyment was almost three times larger than the increase in self-efficacy ($\mu^2_{\text{PA enjoyment}} = 0.112$ versus $\mu^2_{\text{self-efficacy}} = 0.041$). The interaction time by type of intervention (exercise versus stress management) and the main factor type of intervention had no effect in both analyses [PA enjoyment: $F_{\text{condition}(1,\ 58)} = 0.029$, $p = 0.866$, $F_{\text{interaction}(2,\ 116)} = 0.040$, $p = 0.961$; self-efficacy: $F_{\text{condition}(1,\ 63)} = 0.012$, $p = 0.915$, $F_{\text{interaction}(2,\ 126)} = 0.150$, $p = 0.860$]. Thus, the factor type of intervention was left out in an additional analysis yielding very similar results [PA enjoyment: $F_{(2,\ 118)} = 7.412$, $p = 0.001$, $\mu^2 = 0.112$; self-efficacy: $F_{(2,\ 128)} = 2.708$, $p = 0.71$, $\mu^2 = 0.041$]. *Post-hoc* analyses revealed that the significant increase in PA enjoyment and marginally in self-efficacy only took place between T1 und T2 ($p_{\text{PA enjoyment}} < 0.001$; $p_{\text{self-efficacy}} = 0.091$), thus during the intervention. The difference to baseline remained significant at T3 ($p_{\text{PA enjoyment}} = 0.006$; $p_{\text{self-efficacy}} = 0.025$).

Additional Analyses: Factors Related to Change in PA Enjoyment

To examine factors being associated with the significant increase in PA enjoyment (between T1 and T2) at first bivariate correlations were regarded (see **Table 3**). All variables from T1 and T2 which correlated at least marginally ($p < 0.10$) with $\Delta_{\text{T1-T2}}$PA enjoyment [i.e., age, change (T1-T2) in iPAL, chemotherapy status, PA enjoyment at T1, change (T1-T2) in self-efficacy] were included in a regression analysis as independent variables (dependent variable = $\Delta_{\text{T1-T2}}$PA enjoyment). The regression analysis could explain 37% of the variance in the change of PA enjoyment. Low PA enjoyment at T1 ($\beta = -0.472$, $t = -4.437$, $p < 0.001$), a high increase in iPAL between T1 and T2 ($\beta = 0.249$, $t = 2.389$, $p = 0.020$) and a younger age ($\beta = -0.215$, $t = -2.096$, $p = 0.041$) were significant predictors of an increase in PA enjoyment.

DISCUSSION

Increasing evidence hints to the important role of affective factors in the process of behavior change (see introduction). Positive affects might be especially important in an oncological setting, as a cancer diagnosis and oncological treatment is linked to emotional distress and negative emotions (Janz et al., 2013; Deimling et al., 2015). Research shows that being passionate about activities is important for enhancing well-being and lowers

TABLE 3 | Intercorrelations between study variables.

		n	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Intended	1. iPAL T1	67	0.09	0.18	0.25°	0.12	0.14	0.16	0.05	0.08	−0.49***	−0.25*	0.13	−0.13	−0.04	0.07	−0.09	−0.08	0.03	0.05	−0.14	0.16	−0.03	−0.22°
physical activity	2. iPAL T2	67		0.38**	0.2	0.35**	0.32**	0.23°	0.42***	0.42**	0.82***	0.33**	−0.30*	0.17	0.15	0.03	0.16	0.24°	0.00	0.28*	0.01	0.05	0.04	−0.18
level (iPAL)[a]	3. iPAL T3	67			0.09	0.15	0.19	0.42**	0.34**	0.36**	0.23°	0.91***	0.77***	0.06	0.11	0.04	−0.09	0.00	0.02	0.16	−0.03	0.02	−0.05	−0.10
PA enjoyment[b]	4. PA enjoyment T1	62				0.62***	0.36**	0.37**	0.19	0.36**	0.05	0.00	−0.03	−0.51***	−0.53***	−0.23°	−0.17	0.01	0.20	0.03	−0.16	−0.02	0.02	−0.19
	5. PA enjoyment T2	65					0.51***	0.27*	0.30*	0.31*	0.27*	0.11	−0.09	0.35***	−0.07	−0.40**	0.05	0.06	0.00	0.01	−0.24°	−0.23°	0.12	−0.03
	6. PA enjoyment T3	66						0.43***	0.27*	0.53***	0.20	0.13	−0.02	0.17	0.60***	0.59***	−0.10	0.14	0.26*	−0.05	−0.03	−0.18	−0.05	−0.09
Self-efficacy[b]	7. Self-efficacy T1	66							0.45***	0.54***	0.11	0.34**	0.26*	−0.15	0.07	0.15	−0.48***	−0.41**	0.10	−0.02	−0.08	−0.05	−0.05	−0.13
	8. Self-efficacy T2	67								0.52***	0.34**	0.31**	0.06	0.15	0.10	−0.05	0.57***	0.14	−0.49***	0.01	0.02	0.02	0.03	−0.02
	9. Self-efficacy T3	66									0.32**	0.32**	0.08	−0.07	0.16	0.23°	0.04	0.55***	0.49***	−0.05	−0.05	−0.06	−0.10	−0.28*
Change-scores	10. ΔiPAL T1-T2	67										0.43***	−0.33**	0.24°	0.17	0.00	0.19	0.26*	−0.02	0.21°	0.09	−0.05	0.05	−0.04
	11. ΔiPAL T1-T3	67											0.71***	0.11	0.12	0.02	−0.05	0.04	0.00	0.13	0.03	−0.05	−0.04	−0.01
	12. ΔiPAL T2-T3	67												−0.05	0.01	0.02	−0.19	−0.16	0.02	−0.03	−0.04	−0.02	−0.08	0.02
	13. ΔPA enjoyment T1-T2	61													0.59***	−0.15	0.28*	0.07	−0.22°	−0.04	−0.03	−0.22°	0.16	0.26*
	14. ΔPA enjoyment T1-T3	61														0.71***	0.03	0.10	0.07	−0.04	0.12	−0.15	−0.05	0.09
	15. ΔPA enjoyment T2-T3	61															−0.15	0.09	0.28*	0.00	0.13	0.05	−0.18	−0.09
	16. Δself-efficacy T1-T2	66																0.52**	−0.55***	−0.04	0.07	0.06	0.10	0.12
	17. Δself-efficacy T1-T3	66																	0.44***	−0.07	0.04	−0.01	−0.06	−0.19
	18. Δself-efficacy T2-T3	66																		−0.06	−0.07	−0.08	−0.13	−0.27*
Other	19. Type of intervention	67																			0.04	0.10	0.10	−0.07
	20. Sex	67																				0.07	−0.10	0.18
	21. Age	67																					0.26*	0.02
	22. Metastases	67																						0.32**
	23. Chemo-therapy	67																						

[a]*In minutes per week (practiced during the last week);*

[b]*On a scale from 1 to 4; type of intervention: 0 = stress-management, 1 = exercise; sex: 0 = male, 1 = female; metastases: 0 = no, 1 = yes; chemo-therapy: 0 = currently not, 1 = currently chemo-therapy;* °$p < 0.10$, *$p < 0.05$. **$p < 0.01$. ***$p < 0.001$.

TABLE 4 | Hierarchical regression analysis predicting intended physical activity level (iPAL) at T2 and T3 ($N = 61$).

Step	Predictor	$\beta_{step\ 1}$	$\beta_{step\ 2}$	$RW_{\%}$
AV = iPAL at T2				
1:	Type of intervention[a]	0.32**	0.33**	25.8
	iPAL T1	0.22°	0.20°	1.5
	Self-efficacy T1[b]	0.35**	0.27*	22.1
	Δself-efficacy T1-T2	0.29*	0.20	16.3
2:	PA enjoyment T1[b]		0.24°	16.8
	ΔPA enjoyment T1-T2		0.32*	17.5
R^2 for model		0.28	0.36	
Adjusted R^2		0.23	0.28	
ΔR^2 for last step		0.28**	0.08°	
AV = iPAL at T3				
1:	Type of intervention[a]	0.11	0.11	9.9
	iPAL T1	0.12	0.14	10.3
	Self-efficacy T1[b]	0.46**	0.47**	69.1
	Δself-efficacy T1-T2	0.12	0.09	5.5
2:	PA enjoyment T1[b]		−0.05	2.9
	ΔPA enjoyment T1-T2		0.11	2.3
R^2 for model		0.22	0.24	
Adjusted R^2		0.16	0.15	
ΔR^2 for last step		0.22**	0.02	

[a] *Type of intervention: 0 = stress-management, 1 = exercise;*
[b] *On a scale from 1 to 4; °$p < 0.10$ *$p < 0.05$.**$p < 0.01$.*

cancer worry (Burke et al., 2012). Our analysis focused on the role of PA enjoyment. With regard to #PA of cancer patients, PA enjoyment was compared to the classical cognitive factor self-efficacy.

The main result of our study was that baseline PA enjoyment as well as change in PA enjoyment (T1-T2) predicted the iPAL of cancer patients directly after the intervention. A relative weight analysis showed that the effect of PA enjoyment was comparable in its size to the one of the well-established cognitive factor self-efficacy. This is in line with previous studies showing the prominent role of PA enjoyment in predicting PA behavior in healthy adults (e.g., Rhodes et al., 2010; Nasuti and Rhodes, 2013; Lewis et al., 2016). As many people react with distress and depressive symptoms when being confronted with a cancer diagnosis (Jayadevappa et al., 2012; Jones et al., 2015), affective factors might play an especially important role in the oncological setting. Being physically active is one of several self-management strategies cancer patients use to actively deal with the disease (Shneerson et al., 2015). Research has found that regular PA can reduce depressive symptoms and improve the affective mental state (Craft et al., 2012; Mishra et al., 2012). A few mostly correlational studies have already shown that PA enjoyment is an important predictor of PA behavior also in oncological settings (Rogers et al., 2008; Charlier et al., 2013). In these studies PA is compared to other social cognitive factors in explaining cancer patients' PA. PA enjoyment always showed significant mostly moderate associations with PA (e.g., $r = 0.4$ in the study by Rogers et al., 2008).

While we found a significant effect of PA enjoyment on iPAL directly after intervention (at T2), surprisingly, PA enjoyment did not have any influence on iPAL at the 10-week follow up (T3). This is in contrast to findings of Lewis et al. (2016), who compared the relative importance of PA enjoyment and self-efficacy in a longitudinal study with a 12 months follow up in healthy adults, and found that self-efficacy was no longer a significant predictor of PA level when PA enjoyment was controlled. One reason for the more relevant role of PA enjoyment in this study by Lewi et al. compared to ours might be that Lewi's study assessed PA enjoyment more detailed with the 18-item PACES scale (Kendzierski and DeCarlo, 1991). However, our result is comparable to—to our knowledge—the only previous PA promotion trial among oncological patients in which the role of PA enjoyment was examined among 41 breast cancer survivors (Rogers et al., 2011). They found an increase in PA enjoyment directly post intervention as well, but PA enjoyment did not mediate the intervention effect on PA at a 3 months follow-up (barrier self-efficacy on the other hand showed this mediating effect).

If results of our study and the one by Rogers et al. (2011) can be replicated, reasons have to be examined why PA enjoyment is a significant predictor of long term PA in the healthy population (Lewis et al., 2016) but not in an oncological setting. For patients living with a serious disease such as cancer, cognitive factors might be more relevant for maintaining their PA level than affective factors in the long run. For example, in an unpublished survey of our working group among 193 cancer patients of various entities we found that only 13% of patient engaged in physical activities they preferred to do. Thus, cancer patients often cannot carry out the activities they really enjoy (for example playing soccer), but have to choose a suitable type of PA according to the limitations of their illness and the treatment(s) (for example Nordic Walking). Moreover, treatment related barriers (such as side-effects, fatigue, etc.) might make it additionally difficult for oncological patients to maintain their PA level compared to healthy adults (Brawley et al., 2002; Midtgaard et al., 2009; Blaney et al., 2013), pointing out the prominent role of barrier self-efficacy for long term PA.

Results of our study furthermore showed an increase in PA enjoyment and also marginally in self-efficacy during a 4-week behavior change intervention (in an exercise intervention as well as in a stress management group). The increase in self-efficacy is in line with Banduras theory (Bandura, 1977, 2000), postulating that feeling mastery experience regarding PA during an intervention should yield an increase in self-efficacy. Compared to the baseline values the increase in PA enjoyment was nearly three times as much as the one of self-efficacy ($\mu^2_{\text{PA enjoyment}} = 0.11$; $\mu^2_{\text{self-efficacy}} = 0.04$). This is very interesting, as there is no theory explaining changes in PA enjoyment. To our knowledge, only one very recent pilot study among 18 rectal cancer patients has examined increases in PA enjoyment while participating in an exercise program (Morielli et al., 2016). Because of the lack in theoretical background as well as empirical evidence, we exploratively analyzed factors being associated with the increase in PA enjoyment: Increases in PA enjoyment were highest in younger patients, in participants with low scores on PA enjoyment at baseline and in participants who were able to considerably increase their iPAL during the intervention. Looking at this last factor leads to the assumption that changes in PA enjoyment might be related to mastery experience as well. Other potential factors like social aspects of exercising together (including the sources of self-efficacy *vicarious experience* and *personal persuasion*) or physical arousal during exercising (similar to the last source of self-efficacy) might be relevant as well and should be examined in future research. Moreover, the characteristics being a younger patient and having low scores on PA enjoyment should be prescreened in future studies and in current counseling initiatives to define the most valuable group for PA behavior change (trials) in cancer patients. Furthermore, within these patient groups the value of affective exercise components like competition-orientated tasks should be integrated in future study designs.

Our study has several limitations. Firstly, PA enjoyment has been measured with two items only. Although it has a good internal consistency and is based on a measure used in other oncological studies (e.g., Rogers et al., 2011, 2015), a multi-item measure such as the PA enjoyment Scale (PACES; Kendzierski and DeCarlo, 1991) would be preferable and would allow more differentiated analysis. As PA enjoyment was compared to self-efficacy which was assessed much more in detail, our results might be affected by this unequal assessment methods. Secondly, analyses were based on self-report measure for iPAL only and were restricted on exercise-related physical activities instead of PA in general. Thirdly, the focus of this article was limited to self-efficacy and PA enjoyment. Other affective factors besides PA enjoyment (e.g. affective attitudes, affective outcome expectancies, fear of PA) have not been taken into account and might be more relevant for explaining long term PA behavior of cancer patients. Lastly, the intervention study did not include a usual care control group. Results showed an increase in PA enjoyment in both the exercise and the stress management group. Thus, it might be that PA enjoyment increased through the social contact with the intervention staff. However, people of the stress management group also engaged more frequently in PA after the intervention. Thus, probably not the intervention itself but the increase in PA predicted if participants enjoyed PA more after the intervention (Liao et al., 2015).

Future research should bring the single constructs—self-efficacy and PA enjoyment—into a broader context. For example, a classical social cognitive theory including self-efficacy (e.g., TPB or SCT) could be compared to a theory focusing on affective factors. One of the rare affective theories called "affect and health behavior framework" was proposed by Williams and Evans (2014). This complex model suggests pathways—for example automatic and reflective affect processing or affectively charged motivation—through which affect related concepts interrelate and influence health behavior. It would be interesting to test this framework in the PA and cancer domain empirically.

In conclusion, our study was the first study examining the relative importance of PA enjoyment in comparison to the classical cognitive factor self-efficacy in a PA promotion intervention for cancer patients. At least in the short term affective factors such as PA enjoyment seem to play an important role for cancer patients to increase their PA level.

AUTHOR CONTRIBUTIONS

NU contributed substantially to the conception and design of the work, performed statistical analyses and drafted the manuscript. JW supervised and supported the conception, design and implementation of the study and revised the work critically. MS supervised and supported the conception and design of the study, interpreted the data of the work and revised the work critically. All authors read and approved the final manuscript.

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Relationships between Psychophysiological Responses to Cycling Exercise and Post-Exercise Self-Efficacy

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Although self-efficacy (SE) is an important determinant of regular exercise, it is unclear how subjective and physiological states before, during, and after the exercise session affects post-exercise SE. The aim of this study was to clarify subjective and physiological factors affecting post-exercise SE assessed after a single exercise session at a physiologically equivalent level. Forty-three healthy volunteers (28 women, 15 men) completed an 82-min experimental session, comprising a 22-min pre-exercise rest, a 30-min steady-state cycling exercise at moderate intensity [40% of heart rate (HR) reserve], and a 30-min post-exercise rest. We measured physiological (HR) and subjective [Rating of Perceived Exertion (RPE), Feeling Scale (FS)] states during the experimental session. Autonomic states were assessed by power spectral analysis of heart rate variability (HRV) during pre- and post-exercise rest. Post-exercise SE, which was the participants' confidence in their ability to perform the 30-min exercise that they had just performed, was assessed at 30-min post-exercise. A stepwise multiple regression analysis, with post-exercise SE as the dependent variable and physiological and subjective measures of the exercise as candidate explanatory variables, showed that post-exercise SE was negatively correlated with RPE and positively correlated with FS at the end of the 30-min exercise. In addition, post-exercise SE was negatively correlated with high-frequency power of the post-exercise HRV, an index of parasympathetic function. These results indicate that post-exercise SE is related not only to subjective responses to the exercise but also to autonomic response after the exercise.

Keywords: post-exercise self-efficacy, perceived exertion, heart rate variability, autonomic response, multiple regression analysis

INTRODUCTION

The beneficial effects of exercise and physical activity on the development and maintenance of cardiorespiratory, musculoskeletal, and neuromotor fitness in most adults have been widely demonstrated (World Health Organization, 2010; Garber et al., 2011). Therefore, exercise quality and quantity recommendations have been included in the guidelines of the American College of Sports Medicine (ACSM) and the American Heart Association for healthy adults

(Haskell et al., 2007). Nonetheless, physical inactivity remains a major public health problem in many industrialized countries (Kohl et al., 2012). Although regular exercise can clearly prevent many health problems, many find it difficult to adopt and adhere to prescribed exercise programs. This could be because, even when exercise intensity is defined at physiologically or self-selected equivalent levels, there are considerable inter-individual differences in physiological and subjective responses to exercise (Ekkekakis and Lind, 2006; Rose and Parfitt, 2007, 2010, 2012; Ekkekakis et al., 2009; DaSilva et al., 2011).

According to previous studies, exercise self-efficacy (SE) is an important determinant in the adoption and maintenance of a regular exercise regimen (McAuley and Blissmer, 2000). SE refers to the belief in one's capability to successfully execute the actions necessary to satisfy specific situational demands (Bandura, 1997). McAuley et al. (2003) demonstrated that individuals with high exercise SE following a 6-months exercise program reported high activity levels at the 6- and 18-months follow-ups. Moreover, McAuley et al. (2007) demonstrated that many active individuals with high exercise SE at the 2-years follow-up reported still being active at the 5-years follow-up. Thus, high exercise SE was still associated with high physical activity levels for a considerable period afterward. Therefore, factors affecting exercise SE must be revealed to enable the promotion of prescribed exercise programs.

Bandura (1997) identifies four factors affecting SE: mastery experience, vicarious experience, social persuasion, and interpretations of physiological response. Previous studies suggest that exercise SE varies according to experiential and social factors: current exercise behavior or physical activity level (McAuley et al., 2003; Magnan et al., 2013), environmental support (McAuley et al., 2000, 2003), or pre-exercise SE (Pender et al., 2002). These results suggest that individuals who had a successful experience of and a better environment for exercise program performance strengthened their pre-exercise SE, which then promoted adherence to the exercise program easily. On the other hand, pre-exercise SE in individuals without successful exercise experience remains consistently low.

Previous studies demonstrated that affective responses to the exercise, which reflects interpretations of physiological response, also influenced exercise SE (Pender et al., 2002; McAuley et al., 2003; Focht et al., 2007; Kwan and Bryan, 2010; Magnan et al., 2013). For example, SE levels after the exercise increased (Katula et al., 1999; Pender et al., 2002) or decreased (Katula et al., 1999; Focht et al., 2007; Welch et al., 2010) compared with those before the exercise. This divergence was partly due to exercise intensity (Katula et al., 1999; Welch et al., 2010). These results indicated that exercise SE can be modified depending on individual subjective states during exercise, such as Rating of Perceived Exertion (RPE; Borg, 1982) and Feeling Scale (FS; Hardy and Rejeski, 1989), and the exercise experience can result in a successful experience with high exercise SE or an unsuccessful experience with low exercise SE. That is, an affective response to the exercise and the underlying physiological response might be one of the key factors in changing individual exercise SE.

It is well-known that the RPE provides a relatively good estimate of actual heart rate (HR) during exercise. In addition, it is generally believed that affective state correlates with autonomic nervous system activity (Ekman et al., 1983; Christie and Friedman, 2004; Kreibig, 2010). Spectral analysis of heart rate variability (HRV) is an established non-invasive tool that can be used to study the autonomic control of HR at rest (TaskForce, 1996; Perini and Veicsteinas, 2003; Sandercock and Brodie, 2006). For example, using the HRV indices, Sakuragi and Sugiyama (2006) indicated that regular walking exercise improved mood states and shifted autonomic balance to parasympathetic predominance. Weinstein et al. (2007) reported that reduced parasympathetic activity in the baseline period correlated with the increases in negative mood symptoms in the exercise-withdrawal group. From these results, we considered that autonomic activity might be related to subjective responses to exercise and post-exercise SE. However, it is unclear how physiological measures before, during, and after the exercise session relate to post-exercise SE, directly or indirectly. Therefore, as the first step for examining the detailed relationship between interpretations of physiological response to exercise and post-exercise SE, it is important to focus the subjective (RPE and FS) and/or physiological measures (HRV indices) against a steady-state exercise session at a physiologically equivalent intensity level.

The aim of the present study was to clarify the subjective and/or physiological (especially autonomic) factors affecting post-exercise SE assessed after a single exercise session at a physiologically equivalent level. We hypothesized that post-exercise SE is related to not only subjective but also physiological (especially autonomic) measures. For this purpose, we measured subjective and physiological responses to a 30-min steady-state cycling exercise performed at moderate intensities and recorded post-exercise SE 30 min after the exercise. In order to focus the effect of the subjective and/or physiological (especially autonomic) responses to the exercise on post-exercise SE, we asked no question about experiential and social factors beforehand. Furthermore, only post-exercise SE was assessed with the intention of minimizing the aftereffect of self-reported pre-exercise SE. Next, we attempted to identify significant factors affecting post-exercise SE among the measured subjective and physiological variables. However, it is unclear what physiological variables relate to post-exercise SE and how subjective variables interact with them. Therefore, we used a stepwise multiple regression analysis as an exploratory method. In this analysis, post-exercise SE was the dependent variable and physical characteristics and subjective and physiological responses to the exercise were candidate explanatory variables.

MATERIALS AND METHODS

Participants

Forty-three healthy volunteers (28 women, 15 men, age range: 18–24 years-old) not taking any medication or undergoing treatment were sampled. They were recruited from undergraduate student populations at Showa Women's

University and Nihon University. All participants signed an informed consent document before participating in an experimental session and measured their body weight and height (InBody J10; Biospace, Co., Ltd., Seoul, Korea) to calculate their body mass index (BMI). Participants were asked to have a caffeine-free meal at least 2 h before visit to our laboratory. We confirmed by interview that they did not engage in regular exercise, competitive sports, or manual labor, and did not use bicycle ergometer frequently. After completing all experimental procedures, they received a monetary reward. This study was approved by the ethics committee of Showa Women's University and School of Pharmacy, Nihon University.

Post-exercise Self-efficacy

Our post-exercise SE scale was modified from McAuley's Exercise Self-Efficacy Scale (McAuley et al., 1993), and comprised three items on participants' confidence in their ability to perform the 30-min exercise that they had just performed. The items included (1) "I can perform the 30-min exercise three to five times per week at a 10% increased level of intensity from the level I just maintained," (2) "I can perform the 30-min exercise three to five times per week at the same level of intensity as the level I just maintained," and (3) "I can perform the 30-min exercise three to five times per week at a 10% reduced level of intensity from the level I just maintained." Participants answered each item on an 11-point scale ranging from 0% (*not at all confident*) to 100% (*highly confident*). Before the experimental session, one of the authors (EM) explained to participants the method for assessing post-exercise SE. Participants were instructed to rate the SE scales based on their confidence about their execution of the exercise that they had just performed. The average of the responses to the three-item questionnaire was used in the data analysis. McAuley's Exercise Self-Efficacy Scale demonstrated good internal consistency ($\alpha = 0.92$; McAuley et al., 1993). Our measures also demonstrated good internal consistency ($\alpha = 0.92$).

Subjective Measures

Participants' subjective states were assessed using the RPE (Borg, 1982) and the FS (Hardy and Rejeski, 1989). One of the authors (EM) orientated each participant regarding completion of the RPE and FS just before an experimental session. The 15-point RPE scale, ranging from 6 (*no exertion at all*) to 20 (*maximal exertion*), was used to estimate perceived whole-body exertion. The 11-point FS, which ranges from −5 (*very bad*) to +5 (*very good*), measured basic or core affective valence (pleasant – unpleasant).

Experimental Session

Each participant conducted a single experimental session individually, and the experiment was performed under the control of two or more researchers. An experimental session lasted 82 min, comprising a 22-min pre-exercise rest (Pre), a 30-min exercise (Ex), and a 30-min post-exercise rest (Post; **Figure 1**). Participants breathed freely, and their HRs were continuously monitored throughout the session. Participants exercised on an electrically braked bicycle ergometer (Aerobike 900U-ex, Konami Sports & Life, Co., Ltd., Tokyo, Japan). Exercise intensity was set at 40% of HR reserve (HRR). Thus, the target HR during exercise for each participant was calculated as follows: target HR = resting HR + 0.4 × (maximal HR – resting HR). Maximal HR was calculated as 220 – age. Resting HR was the mean HR value during a 15-min Pre period.

The experimental session began after participants' 10-min rest on a chair to familiarize themselves with the experimental setting. During the Pre period, participants sat in a chair next to a bicycle ergometer. Twenty minutes after the start of the Pre period (Pre-20), participants recorded their FS, then moved from the chair to the bicycle ergometer. At Pre-22, participants started a bicycle exercise. One of the authors (EM) gradually increased the bicycle's workload during the first 5 min of the Ex period and adjusted it so the participants could exercise at their target HR levels. Afterward, while participants' HR were monitored, the workload was adjusted every 5 min during the Ex period. This enabled the participants to perform steady-state exercise at their target HR levels (maximal adjustment range was ±10W in a single session). Thirty minutes after the start of the Ex period (Ex-30), participants completed the bicycle exercise and immediately recorded their RPE and FS on the ergometer. After that, they moved from the ergometer to the chair, sitting in the chair in a relaxed state during the Post period. Thirty minutes after the start of the Post period (Post-30), participants recorded their FS and experiential post-exercise SE. We recorded RPE and FS only at the end of each component of the session (only at Ex-30 for RPE, and at Pre-20, Ex-30, and Post-30 for FS) because it was easy to focus self-report measurements for the participants.

Physiological Data Recording and Analysis

Throughout the experimental session, participants' HRs were continuously monitored using a three-lead electrocardiogram (ECG; BSM-2401 ECG monitor, Nihon Kohden, Tokyo, Japan). The output signal from the ECG monitor, a train of rectangular impulses corresponding to the QRS spikes, was stored sequentially by a bio-amplifier recording device (Polymate II AP216, TEAC, Japan) and used for the subsequent off-line analysis (sampling rate = 1,000 Hz). The period between consecutive heartbeats (R–R intervals: RRI) was calculated using all of the output signal data collected during an 82-min experimental session. Next, a trained researcher (one of the authors, KY) searched the RRI data for outliers, which would likely have been caused by bodily movements during the exercise, and corrected these by either omitting (for extra beats) or inserting beats (for doubled or tripled beats). The mean percentage of abnormal beats during an 82-min experimental session was 0.23%; most of these were observed during the transition between the chair and the bicycle ergometer. From the corrected RRI data, steady-state RRI data (5–20 min in the Pre period, 10–25 min in the Ex period, and 10–25 min in the Post period) were extracted and converted to HR data (beats/min), and the average HR was calculated for each steady-state 15-min period (HR_{mean}). Actual %HRR values in the Ex period were then calculated.

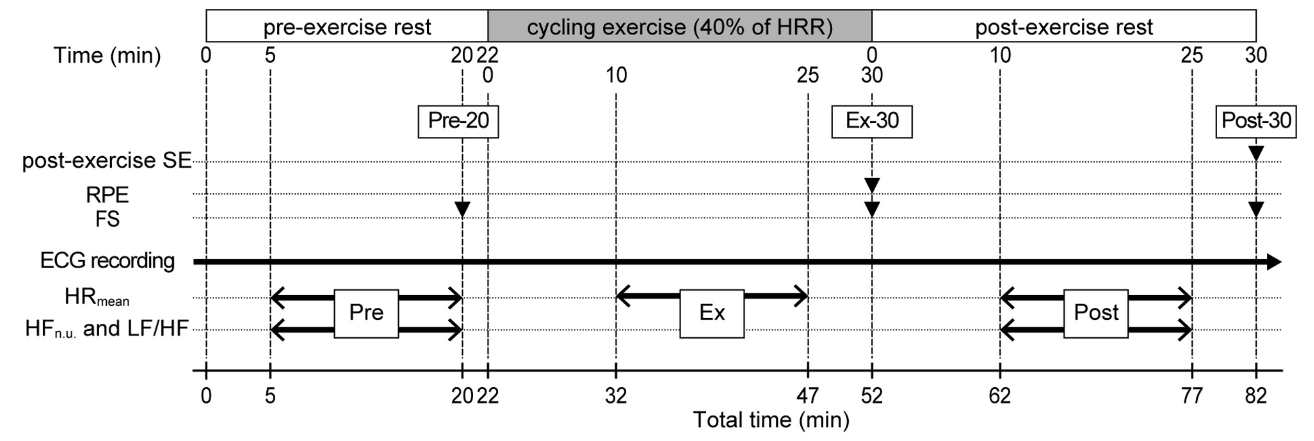

FIGURE 1 | Experimental protocol. An 82-min experimental session comprised a 22-min pre-exercise rest (Pre), a 30-min exercise (Ex), and a 30-min post-exercise rest (Post). Filled triangles indicate the time points for recording of subjective measures represented on the left. Two-headed arrows indicate the time periods for steady-state HR data represented on the left. SE, self-efficacy; RPE, rating of perceived exertion; FS, Feeling Scale; %HRR, percentage of heart rate reserve.

TABLE 1 | Participant characteristics and exercise parameters.

	Female (n = 28)	Male (n = 15)
Age (year)	21.0 ± 1.2	20.7 ± 1.7
Height (cm)	158.9 ± 4.7	169.4 ± 4.4*
Weight (kg)	53.2 ± 5.5	62.3 ± 8.7*
BMI (kg/m^2)	21.1 ± 2.0	21.7 ± 2.6
Workload (W)	70.4 ± 11.3	99.3 ± 23.3*
%HRR	40.3 ± 2.0	39.3 ± 3.1

*Data presented as mean ± SD. BMI, body mass index. *$p < 0.05$; Unpaired t-tests show significant differences between male and female participants.*

Next, the steady-state RRIs were interpolated and re-sampled at 10 Hz using a cubic spline function to obtain equally spaced samples. Then, power spectral analysis of the HRV data was performed using a fast Fourier transform algorithm. The data were categorized into high-frequency (HF; 0.15–0.40 Hz) and low-frequency (LF; 0.04–0.15 Hz) bands and calculated as integrals under the respective power spectral density functions (ms^2). HF power in normalized units [HFn.u. = HF/(LF + HF) × 100] was calculated as an index of parasympathetic function, and the LF/HF ratio was calculated as an index of sympathovagal balance (TaskForce, 1996). These data analyses were performed using Matlab R2012b (MathWorks, Natick, MA, USA).

Statistical Analysis

As a prerequisite for examining the relation between post-exercise SE and subjective and physiological measures, we needed to confirm whether the experiment was carried out as planned (participant characteristics and experimental settings) and how participants responded to the exercise subjectively and physiologically. Therefore, we first conducted two-sample t-tests on the participant characteristics and exercise parameters for women and men. Next, we examined temporal changes of subjective (FS) and physiological measures (HR_{mean}, $HF_{n.u.}$, and LF/HF) as follows. On FS and HR_{mean}, a repeated measures ANOVA was conducted with three time points (Pre-20, Ex-30, and Post-30) or periods (Pre, Ex, and Post) as the within-subjects factor. For the repeated measures ANOVA, we used Mauchly's test to evaluate the sphericity assumption, and, when necessary, a Greenhouse–Geisser procedure was used to correct the degrees of freedom. If necessary, *post hoc* multiple comparisons were conducted by using paired t-tests with Bonferroni correction. On the HRV indices in Pre- and Post-exercise resting periods (HFn.u. and LF/HF during Pre and Post), paired t-tests were conducted. Finally, in order to identify some of the factors contributing to post-exercise SE, we conducted a stepwise multiple regression analysis. We chose post-exercise SE as the dependent variable and participants' physical characteristics (BMI), physiological and subjective states during pre-exercise rest (HR_{mean}, $HF_{n.u.}$, and LF/HF in Pre and FS at Pre-20), exercise (HR_{mean} in Ex and RPE and FS at Ex-30), and post-exercise rest (HR_{mean}, $HF_{n.u.}$, and LF/HF in Post and FS at Post-30) as candidate explanatory variables. All statistical analyses were performed using SPSS Statistics 19.0 (IBM SPSS, Chicago, IL, USA). The data were presented as mean ± SD.

RESULTS

Participant Characteristics and Exercise Settings

In **Table 1**, participant characteristics (age, height, weight, and BMI) and exercise settings (workloads of bicycle ergometer and %HRR) are shown for women (n = 28) and men (n = 15). Although there were significant sex differences in height ($t[41] = 7.17$, $p < 0.01$, $d = 2.32$) and weight ($t[41] = 4.21$, $p < 0.01$, $d = 1.25$), no significant differences were observed regarding BMI ($t[41] = 0.84$, $p = 0.41$, $d = 0.26$). Four participants were categorized as "underweight" (from 16.0 to

18.5) and five were "overweight" (from 25 to 30), while 34 participants were categorized as "healthy weight" (from 18.5 to 25). No participants were "severely underweight" (BMI < 16.0) or "obese" (BMI ≥ 30). Next, there was a significant sex difference in workloads of bicycle ergometer ($t[41] = 5.50$, $p < 0.01$, $d = 1.58$), while there was no significant difference in %HRR ($t[41] = 0.85$, $p = 0.40$, $d = 0.40$). These results provide strong evidence that most participants had normal physical characteristics, and both female and male participants exercised at relatively equivalent intensity as planned. Since there was no significant sex difference on age, BMI, and %HRR, we pooled all participants' (women and men) data in the following analyses.

Subjective and Autonomic Responses to Steady-state Cycling Exercise

Subjective and physiological responses to exercise are shown in **Table 2**. A repeated measures ANOVA on FS scores revealed no significant effect of time points ($F[2,42] = 2.02$, $p = 0.13$, $\eta_p^2 = 0.05$). This indicates that FS scores had relatively large individual differences and did not change in a uniform way for all participants. A repeated measures ANOVA on HR_{mean} revealed a significant effect of time periods ($F[2,42] = 2960.5$, $p < 0.01$, $\eta_p^2 = 0.98$), and *post hoc* multiple comparison revealed that there were significant differences in the HR_{mean} between Pre and Ex ($t[42] = -63.3$, $p < 0.01$, $d = 10.33$), Ex and Post ($t[42] = 58.9$, $p < 0.01$, $d = 9.60$), and Pre and Post periods ($t[42] = -6.29$, $p < 0.01$, $d = 0.58$). This indicates that HR changed similarly for all participants according to exercise session, and the HR_{mean} in Post did not completely return to the baseline level (the HR_{mean} in Pre). A paired t-test revealed that $HF_{n.u.}$ (index of parasympathetic function) was significantly larger in Post than in Pre ($t[42] = 2.93$, $p < 0.01$, $d = 0.26$), and the LF/HF ratio (index of sympathovagal balance) was significantly smaller in Post than in Pre ($t[42] = -2.58$, $p < 0.05$, $d = 0.35$). These results indicate that autonomic states were different before and after the exercise. The post-exercise SE values at Post-30 were around 70 with a substantial inter-individual difference (range: 20–100).

Stepwise Multiple Regression Analysis

Table 3 shows the results of a stepwise multiple regression analysis for post-exercise SE at Post-30. In the final model, the post-exercise SE at Post-30 was negatively correlated with RPE at Ex-30, positively correlated with FS at Ex-30, and negatively correlated with $HF_{n.u.}$ in Post. **Figure 2A** shows the relationships between post-exercise SE at Post-30 and RPE at Ex-30; participants with high RPE scores at Ex-30 assessed their post-exercise SE at Post-30 as low. **Figure 2B** shows the relationships between post-exercise SE at Post-30 and FS at Ex-30; participants with high FS scores at Ex-30 assessed their post-exercise SE at Post-30 as high. **Figure 2C** shows the relationships between post-exercise SE at Post-30 and $HF_{n.u.}$ in Post; participants with high $HF_{n.u.}$ (index of parasympathetic activity) in Post assessed their post-exercise SE at Post-30 as low. These results indicate that, when participants reported low RPE and high FS at the end of the exercise and revealed low parasympathetic activity during post-exercise resting period, they assessed post-exercise SE at Post-30 as high.

TABLE 2 | Subjective and physiological responses to exercise and post-exercise SE.

		Pre-exercise rest	Exercise	Post-exercise rest
Subjective responses	RPE		13.0 ± 2.1	
	FS	1.28 ± 1.56	1.88 ± 1.53	1.49 ± 1.74
Physiological responses	HR_{mean} (bpm)	69.6 ± 6.5	121.4 ± 2.9	73.3 ± 6.5#
	$HF_{n.u.}$	0.40 ± 0.17		0.36 ± 0.16*
	LF/HF	1.91 ± 1.11		2.43 ± 1.78*
Post-exercise SE (%)				69.4 ± 23.4

*SE, Self-efficacy; RPE, Rating of Perceived Exertion; FS, Feeling Scale; $HF_{n.u.}$, high-frequency power of heart-rate variability in normalized unit; LF, low-frequency power of heart-rate variability. Data are mean ± SD. #p < 0.05; Two-way factorial ANOVA shows a significant main effect of time period. *p < 0.05; Paired t-tests show significant differences between pre- and post-exercise rest.*

TABLE 3 | Result of stepwise multiple regression analysis.

Step	Adjusted R^2	F	Explanatory variable	B	SE	β	t
Dependent variable: post-exercise SE at Post-30							
Step 1	0.146	8.192	RPE at Ex-30	−4.569	1.596	−0.408	−2.861
Step 2	0.542	8.308	RPE at Ex-30	−4.602	1.488	−0.411	−3.093
			FS at Ex-30	5.440	2.029	0.356	2.681
Step 3	0.347	8.445	RPE at Ex-30	−3.846	1.427	−0.343	−2.694
			FS at Ex-30	5.626	1.905	0.369	2.954
			HFn.u. in Post	−48.697	19.170	−0.324	−2.540

SE, Self-efficacy; adjusted R^2, coefficient of determination adjusted for degrees of freedom; B, partial regression coefficient; SE, standard error; β, standardized partial regression coefficient; RPE, Rating of Perceived Exertion; FS, Feeling Scale; $HF_{n.u.}$, high-frequency power in normalized units; Ex, exercise; Post, post-exercise rest.

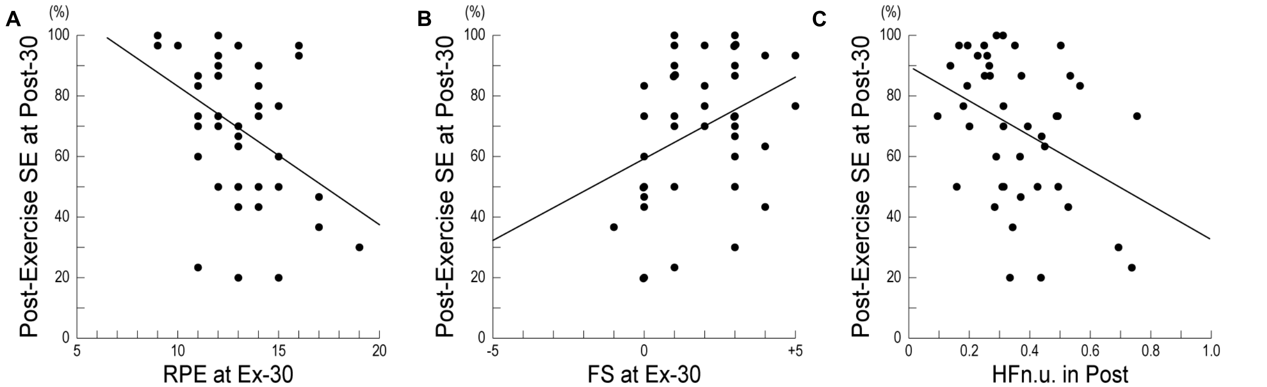

FIGURE 2 | Relationship between post-exercise self-efficacy and subjective or physiological measures. (A) Relationship between post-exercise SE and RPE at Ex-30 ($r = 0.167$, $p < 0.05$). **(B)** Relationship between post-exercise SE and FS at Ex-30 ($r = 0.125$, $p < 0.05$). **(C)** Relationship between post-exercise SE and $HF_{n.u.}$ in Post ($r = 0.145$, $p < 0.05$). SE, Self-Efficacy; RPE, Rating of Perceived Exertion; FS, Feeling Scale; $HF_{n.u.}$, high-frequency power of heart-rate variability in normalized unit.

DISCUSSION

The aims of the present study were to clarify subjective and/or physiological factors affecting post-exercise SE. To achieve this purpose, we recorded subjective (RPE and FS) and physiological (HR_{mean} and HRV indices) responses to a 30-min steady-state cycling exercise at moderate intensity (40% of HRR) and post-exercise SE at 30 min post-exercise. Stepwise multiple regression results suggest that post-exercise SE at the end of the 30 min post-exercise period was mainly dependent on RPE and FS at the end of the exercise and on $HF_{n.u.}$ during post-exercise resting period. To our knowledge, this is the first study revealing the relationship between post-exercise SE and not only subjective but also autonomic measures.

We first conducted a careful check to ensure all participants exercised at the planned intensity levels (40% of HRR) and obtained strong evidence that all participants exercised as planned. Therefore, other variables examined in this study (RPE, FS, and HRV indices) were considered representative of participants' subjective and physiological responses to a 30-min steady-state cycling exercise at the target moderate intensity. Despite such a strict setting of physiologically equivalent exercise intensity, FS scores at Ex-30 had a large inter-individual variability, which is similar to previous results (Rose and Parfitt, 2007, 2010; Haile et al., 2013). On the other hand, Ekkekakis and Lind (2006) and Ekkekakis et al. (2009) showed that the pattern of change in the affective responses differed among normal-weight, overweight, and obese individuals. In our study, however, only five participants were categorized as "overweight," and no participants were "obese." Therefore, it is not likely that BMI was a main factor in the inter-individual FS variability observed in this study. Moreover, post-exercise SE had a substantial inter-individual difference (range: 20–100). This also lends strong support to our hypothesis that post-exercise SE can be altered by many subjective and physiological factors.

This study's "moderate" level was relatively low (range: 40–59% of HRR) in ACSM's exercise intensity classification (Garber et al., 2011). Since we did not recruit participants based on their physical fitness levels, it is highly probable that inactive individuals were included. Previous study demonstrated that, when controlling for physiological values (oxygen uptake or HR) during exercise, individuals with high fitness levels perceived themselves to be under less exertion than did those with low fitness levels (Travlos and Marisi, 1996). Another study reported that, when controlling for subjective value (RPE), individuals with low fitness levels exhibited greater physiological indices during exercise than did those with high fitness levels (Kaufman et al., 2006). That is, we assumed that relatively low exercise intensity might be suitable for an investigation of subjective and/or physiological factors affecting experiential post-exercise SE among our participants with wide range of physical fitness levels. In fact, our participants' RPE scores were relatively high in the above-mentioned ACSM classification (RPE 12–13).

With respect to the physiological measures used during pre- and post-exercise resting periods, HR_{mean} was significantly higher in the Post than in the Pre period. In addition, $HF_{n.u.}$ (index of parasympathetic function) was significantly larger in Post than in Pre and the LF/HF ratio (index of sympathovagal balance) were significantly smaller in Post than in Pre. These results indicate that, probably due to physiological aftereffects of the exercise, participants were sympathetic dominant during post-exercise resting periods after a 30-min steady-state cycling exercise at moderate intensity. This diversity in subjective (RPE and FS) and physiological (HR_{mean} and HRV indices) responses to the exercise might be one of the factors of a substantial inter-individual difference in post-exercise SE. Therefore, it is important to reveal factors affecting post-exercise SE using exploratory stepwise multiple regression analyses.

Stepwise multiple regression analysis showed that post-exercise SE at Post-30 was negatively correlated with RPE and positively correlated with FS, at Ex-30. This result indicates that participants with strong perceptions of exertion and bad feelings during exercise typically assessed their confidence in their ability to perform the 30-min exercise that they had just performed as low. This relationship between post-exercise SE and RPE at Ex-30 is similar to a previous finding that RPE scores during exercise partly explained the variance in post-exercise SE (Pender et al., 2002). The interesting aspect of this result is that an extracted affecting factor of post-exercise SE was not HR_{mean} during exercise, which directly reflects exercise intensity, but RPE and FS at the end of the exercise, which indirectly reflects relative exercise intensity through participants' subjective states. That is, participants' post-exercise SE is more strongly influenced by subjective states of physical stress, effort, and fatigue than by physiological cardiovascular states during exercise. Furthermore, post-exercise SE at Post-30 was negatively correlated with $HF_{n.u.}$ in Post. This significant relationship between post-exercise SE and HRV indices was critically interesting. When we consider that the $HF_{n.u.}$ is an index of parasympathetic function, this suggests that participants with high vagal activity (and low sympathetic activity) during the post-exercise resting period tended to assess their post-exercise SE as low. This result suggests that post-exercise SE might be related to the balance of autonomic HR control in the post-exercise resting period.

In this study, we focused one of Bandura's four factors affecting SE: interpretations of physiological response. Therefore, we hypothesized that post-exercise SE is related to physiological and subjective measures to the exercise and focused on the relationships between interpretations of physiological response to the exercise and post-exercise SE. As a result, we demonstrated that post-exercise SE is related not only to subjective responses to exercise but also to autonomic response after the exercise. On the other hand, previous studies reported that other social and experiential factors affect post-exercise SE (McAuley et al., 2000, 2003; Magnan et al., 2013). In addition, pre-exercise SE affected subjective responses to the following exercise (Katula et al., 1999; Jerome et al., 2002; Focht et al., 2007; Magnan et al., 2013). Moreover, it is not clear whether the level of post-exercise SE remains stable over time, especially by the time of the next exercise participation. That is, it is important to examine how post-exercise SE, which is modified according to the exercise participation influences many factors affecting exercise SE afterward. As a next step, therefore, we will try to reveal interactive relationships between pre- and post-exercise SE and many other factors.

Several methodological limitations of this study should be discussed. First, our sample size was small. For multiple regression analysis of our experimental setting (effect size f^2 [large] = 0.35, $\alpha = 0.05$, power = 0.8, number of predictors [explanatory variables] = 12), sample size was *a priori* estimated to 61. On the other hand, statistical power from *post hoc* computing using our data (effect size $f^2 = 0.39$) was 0.61. Based on the small sample size and its statistical power, we have to be careful in interpreting our regression analysis. In addition, the age range of our sample was narrow (18–24 years-old), and none of the participants were of an extreme physical size (BMI: 17.1–26.3). Moreover, we did not collect data on their daily physical activity levels. Further research should be conducted with a larger and more diverse sample, and participant characteristics should be examined closely. Second, the exercise intensity (%HRR) used in this study was based not on a ventilatory threshold but on HR. Since affective (Rose and Parfitt, 2007) and autonomic (Yamamoto et al., 1992) responses during exercise differ above and below one's ventilatory threshold, participants' post-exercise SE may have been affected by whether they surpassed their ventilatory threshold. Third, since applying traditional HRV analysis to exercise HR data remains controversial (Perini and Veicsteinas, 2003; Sandercock and Brodie, 2006), we assessed HRV indices only during pre- and post-exercise resting periods and did not address HRV indices during exercise. Some improved methods for HRV analysis during exercise have been proposed, such as coarse-graining spectral analysis (Yamamoto and Hughson, 1991), Poincaré plot (Tulppo et al., 1999), and time-frequency analysis using short-time Fourier transforms (Cottin et al., 2004; Pichon et al., 2004). Applying these analyses will provide us with information on autonomic HR control during exercise.

In summary, we demonstrated that SE regarding an exercise that participants had just performed is related to exercise-induced subjective and autonomic responses. In particular, one of the contributor to post-exercise SE was $HF_{n.u.}$ in the Post-resting period, which is considered an index of autonomic HR control. This is the first study to examine the relationship between post-exercise SE and HRV indices (which probably reflect autonomic control) after the exercise. Although further research is needed to confirm the methodological validity and reproducibility of these results, the present findings contribute to our understanding of the interactive relationship between post-exercise SE and physiological and subjective states before and during exercise.

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The Exercise–Affect–Adherence Pathway: An Evolutionary Perspective

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The low rates of regular exercise and overall physical activity (PA) in the general population represent a significant public health challenge. Previous research suggests that, for many people, exercise leads to a negative affective response and, in turn, reduced likelihood of future exercise. The purpose of this paper is to examine this exercise–affect–adherence relationship from an evolutionary perspective. Specifically, we argue that low rates of physical exercise in the general population are a function of the evolved human tendency to avoid unnecessary physical exertion. This innate tendency evolved because it allowed our evolutionary ancestors to conserve energy for physical activities that had immediate adaptive utility such as pursuing prey, escaping predators, and engaging in social and reproductive behaviors. The commonly observed negative affective response to exercise is an evolved proximate psychological mechanism through which humans avoid unnecessary energy expenditure. The fact that the human tendencies toward negative affective response to and avoidance of unnecessary physical activities are innate does not mean that they are unchangeable. Indeed, it is only because of human-engineered changes in our environmental conditions (i.e., it is no longer necessary for us to work for our food) that our predisposition to avoid unnecessary physical exertion has become a liability. Thus, it is well within our capabilities to reengineer our environments to once again make PA necessary or, at least, to serve an immediate functional purpose. We propose a two-pronged approach to PA promotion based on this evolutionary functional perspective: first, to promote exercise and other physical activities that are perceived to have an immediate purpose, and second, to instill greater perceived purpose for a wider range of physical activities. We posit that these strategies are more likely to result in more positive (or less negative) affective responses to exercise, better adherence to exercise programs, and higher rates of overall PA.

Keywords: exercise adherence, affect, evolution, perceived utility, hedonic valence, ultimate causes

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INTRODUCTION

Regular physical activity (PA) improves physical health (Haskell et al., 2007; Donnelly et al., 2009) and mental health (Schuch et al., 2011), and prolongs life span (Reimers et al., 2012). However, only 51.6% of US adults meet the national guideline of 1000 kcal/week of PA (Centers for Disease Control and Prevention [CDC], 2013) and approximately 5.3 million people die globally each year due to lack of PA (Lee et al., 2012). Given its well-known benefits, increasing rates of regular PA remains an important public health challenge.

Until recently, research on PA promotion has tended to emphasize cognitive determinants of PA adherence, such as expected health outcomes, self-efficacy, behavioral intentions, and social norms (Marcus et al., 2006; Williams and Marcus, 2012). However, in the past 10–20 years there has been greater attention to affective processes among PA promotion researchers (Ekkekakis, 2003; Ekkekakis et al., 2005; Kiviniemi et al., 2007; Rhodes et al., 2007, 2009; Williams et al., 2008, 2012; Schneider et al., 2009; Kwan and Bryan, 2010a,b; Conner et al., 2011; Rose and Parfitt, 2012; Baldwin et al., 2013). Much of this research has focused on the way people feel in response to intentional exercise—a form of PA performed for the purposes of health and fitness.

Despite the ubiquitous media message that "exercise feels good," it is now clear that the relationship between exercise and affect is not so simple (Emerson and Williams, 2015). While most people tend to *feel good after exercise*, many people—including a large proportion of inactive and unfit individuals who are the targets of PA promotion efforts—*feel bad during exercise* (Ekkekakis et al., 2011). Thus, it is more accurate to say that while almost everyone likes to be finished with exercise, many people actually dislike exercising.

In addition to these scientific findings, evidence that many people dislike physical exertion can be seen by the high rate of escalator or elevator use in lieu of the stairs, the use of human conveyor belts at airports, and the tendency for people to circle around parking lots trying to find a close place to park. Other evidence comes from the wide use of effort-saving devices such as remote controls, electric garage door openers, and electric can openers. It is hard to argue that these automated products are simply used to save time, or that they are only used to assist those who would otherwise be physically incapable of manually performing the relevant tasks.

Perhaps not surprisingly, research has also shown that, consistent with ancient and contemporary theories of human behavior (Hobbes, 1651/2008; Bentham, 1789/2007; Mill, 1861/2012; Usener, 1887/2010; Young, 1952; Cabanac, 1971; Kahneman et al., 1997), those who experience a more negative affective response to exercise are less likely to repeat it in the future, and thus more likely to drop out of exercise promotion programs (Rhodes and Kates, 2015). Thus, from a public health perspective, it is critically important to understand why many people have a negative affective response to a behavior—physical exercise—that is good for their health. That is, why do many people dislike exercising?

The aim of this paper is to attempt to answer this question by taking an evolutionary perspective. We will argue that the negative affective response to exercise is a manifestation of an evolved tendency to avoid energy expenditure that served no immediate adaptive function. In modern environments, this evolved psychological mechanism has led to difficulty with exercise adherence and overall low rates of PA.

In making the above arguments we first highlight the distinction between proximate and ultimate (i.e., evolutionary) causes of behavior. We then apply this distinction in an attempt to understand the evolutionary basis for the low rates of compliance with exercise programs and corresponding low rates of PA. Specifically, we posit that negative affective response to exercise is the proximate psychological mechanism through which the ultimate cause of preventing unnecessary energy expenditure influences poor compliance with exercise programs. We then consider the characteristics of exercise—its intensity and lack of perceived utility—that contribute to a negative affective response to exercise among many individuals. In this context we discuss the concept of *perceived utility of PA* as a cognitive mechanism that evolved to signal when PA had an immediate adaptive payoff, such as when chasing prey, fleeing from predators, or engaging in social play. Finally, we discuss the implications of this model for designing exercise promotion interventions.

PROXIMATE VERSUS ULTIMATE CAUSES OF BEHAVIOR

The biologist Ernst Mayr distinguished between proximate and ultimate causes of behavior (Mayr, 1963; for a similar formulation, see Tinbergen, 1963; for a recent discussion of Mayr's distinction in the context of psychological science, see Scott-Phillips et al., 2011). When trying to understand the causes of behavior, behavioral scientists are often concerned with proximate causes: *How* does the behavior occur? Proximate causes of behavior refer to the *biological or psychological mechanisms* that control the behavior in the here and now. The vast majority of behavioral science research addresses questions of proximate causation, which involve elucidation of physiological, psychological, or social phenomena that explain the target behavior. For example, elucidating the causal mechanisms of unhealthy eating may involve research on individual variability in metabolic processes, food preferences and cravings, ubiquity of environmental food cues, and social norms related to eating (e.g., Roth et al., 2001; Blundell et al., 2005; Davis et al., 2007).

However, according to Mayer, to gain a full understanding of the causes of behavior, it is also necessary to consider ultimate causes: *Why* does the behavior occur? Ultimate causes of behavior refer to the *functional significance* of the behavior from an evolutionary perspective. Questions of ultimate causation assume that biological evolution is largely driven by the process of natural selection whereby genetically based traits that increase the odds of survival and reproduction are more likely to be perpetuated in future generations. Such questions are the subject matter for the fields of sociobiology (Wilson, 2000), behavioral ecology (Cronk, 1991), and evolutionary psychology (Cosmides and Tooby, 1987; Plotkin, 1997).

Importantly, in exploring questions of ultimate causation, one should distinguish between the functional significance of the behavior in the here-and-now versus its functional significance at the time that the pattern of behavior evolved. This point is easily illustrated when considering the caloric overconsumption that is largely responsible for the recent (on an evolutionary timescale) obesity epidemic. Human tendency to consume high fat and sugary foods when available (e.g., Power and Schulkin, 2013; Speakman, 2016) increased the odds of survival and reproduction among human evolutionary ancestors, because such foods were scarce and in those ancestral environments provided a dense energy source (e.g., Keskitalo et al., 2007). However, the same tendencies are maladaptive in modern environments where such foods are abundant (though only "maladaptive" in an evolutionary sense to the extent that such patterns of eating reduce fecundity).

The answers to questions about proximate and ultimate causes of behavior can be integrated. Proximate causes of behavior are the biological and psychological mechanisms through which the ultimate causes of behavior have their influence on the behavior. That is, for an adaptive pattern of behavior to evolve there must be a biological and/or psychological trait(s) that provides the mechanism through which the organism executes the adaptive behavior. The biological/psychological mechanism(s) answers the proximate *how* question. To continue with the example from above, the fact that energy-dense (i.e., sweet and fatty) foods taste good to most humans and thus motivate us to consume such foods is the proximate biological/psychological mechanism through which the evolutionarily adaptive (at the time that it evolved) tendency to eat high fat and sugary foods operates.

PROXIMATE CAUSES OF LOW RATES OF EXERCISE ADHERENCE

To date, most research investigating the behavior of physical exercise has examined questions of proximal causation: How does exercise behavior occur, or not occur? That is, what causes people to engage in exercise, or not, in the here and now?

As noted in the introduction, much of this research has focused on cognitive factors, such as expected outcomes of exercise, self-efficacy, social norms, and behavioral intentions. These cognitive factors help to explain how people successfully set goals, formulate intentions, make plans, and overcome barriers to exercise. But why is it so difficult to exercise to begin with? People do not need to set goals, formulate intentions, make plans, and work hard to overcome obstacles to watch television on a regular basis. Most of us regularly end up in front of the television on most days without any of this cognitive effort (Ekkekakis et al., 2016). So why is it so easy to watch television but so hard to exercise?

The answer, as we have argued above, is that many people generally dislike exercising. That is, we humans tend to have a negative affective response during many types of intentional physical exercise. And the fact that many people dislike exercising is a main reason for the low rates of exercise participation and overall PA. Thus, the human tendency to have a negative affective response to most types of exercise is a proximate cause of the low rates of exercise and PA in the general population.

ULTIMATE CAUSES OF LOW RATES OF EXERCISE ADHERENCE

The tendency for people to engage in, or avoid, physical exercise can also be examined from an evolutionary perspective by addressing the question of ultimate causation: Why does exercise behavior occur, or not occur? That is, what is the functional significance of avoiding exercise behavior?

Certainly, it is not functionally adaptive to avoid exercise in today's modern environment. In fact, exactly the opposite is true. Regular exercise has numerous health benefits that prolong life and increase fertility. However, to address the question of functional significance, it is necessary to conceptualize "function" with respect to the prevailing conditions under which the target behavior evolved. Our evolutionary ancestors—whether protohumans or earlier ancestors—had to perform vast amounts of PA just to obtain food and avoid predators. Thus, if anything, our ancestors, along with other animal species, had the opposite energy balance problem from the one faced by modern humans: taking in enough energy to maintain energy balance given the energy expenditure necessary for survival and reproduction.

Expending energy through extraneous PA that had no purpose other than to expend energy (i.e., exercise) would have decreased the survival and reproductive fitness of human evolutionary ancestors. As a result, selection pressures would have favored the genetic predisposition to conserve energy by avoiding PA that did not serve a direct adaptive function, such as obtaining food, fleeing from predators, or engaging in important social interactions.

In sum, the functional significance of the human tendency to avoid intentional physical exercise is that it allowed us to conserve energy, thus leading to decreased risk of potential energy deficits, and increased likelihood of survival and reproduction among our evolutionary ancestors (for a more detailed argument along these lines, see Lieberman, 2015).

NEGATIVE AFFECTIVE RESPONSE TO EXERCISE AS AN ADAPTIVE PSYCHOLOGICAL MECHANISM

We have thus far argued that the ultimate cause of the low rates of physical exercise is the human tendency to conserve energy; and the proximate cause of the low rates of physical exercise is the human tendency to respond to physical exercise with negative affect. An integration of these causes suggests that the human tendency to respond to physical exercise with negative affect is the proximate psychological mechanism through which the ultimate cause of conserving energy has its effects on the behavior of avoiding physical exercise.

This genetically endowed *exercise–affect–adherence pathway* (Williams, 2008) can be broken down into two dyadic relationships (**Figure 1**): the exercise–affect relationship (path A) and the affect–adherence relationship (path B). In the following sections, we will first more precisely define affective response to

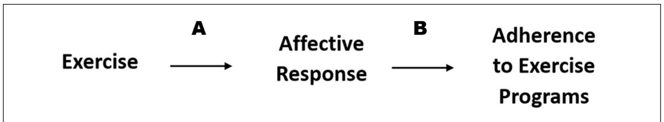

FIGURE 1 | The exercise–affect–adherence pathway. Path **(A)** refers to the domain-specific influence of exercise behavior on affective response. Path **(B)** refers to the domain-general influence of affective response on future exercise behavior.

exercise. Then, we will discuss, in turn, the affect–adherence and exercise–affect relationships.

DEFINING AFFECTIVE RESPONSE TO EXERCISE

According to the circumplex model, *core affect* can be characterized along two dimensions: valence (i.e., good versus bad) and arousal (i.e., high versus low; Russell, 1980; for a discussion of the "positive affect" and "negative affect" dimensions of the "rotated circumplex model" and the confusion caused by these labels, see Ekkekakis, 2013). Distinct affective states, such as specific moods (e.g., peaceful, depressed, irritable, energized) and emotions (e.g., anxious, joyful, angry, sad) represent some combination of core affective valence and arousal that can be arranged in four quadrants. For example, anxiety represents "bad" valence and "high" arousal, whereas joy represents "good" valence and "high" arousal. In addition to core affect, moods and emotions may also involve a triggering environmental stimulus, cognitive appraisals of such stimuli, specific patterns of physiological responses, and facial expressions.

When considering affective response to exercise as a potential determinant of future exercise behavior, rather than as an outcome in its own right (e.g., effects of exercise training on depressive symptoms), it is useful to focus on core affective valence (i.e., feeling good versus bad). The reason affective valence is useful for this purpose is because according to numerous ancient and contemporary theories of *psychological hedonism* (Hobbes, 1651/2008; Bentham, 1789/2007; Mill, 1861/2012; Usener, 1887/2010; Young, 1952; Cabanac, 1971; Kahneman et al., 1997; see also Affective Response to Exercise as a Determinant of Exercise Adherence) people are more likely to repeat behaviors that make them feel good and avoid behaviors that make them feel bad. Thus, when examining how people respond to exercise, the critical issue is whether they feel good or bad rather than whether they feel, for example, anxious versus embarrassed or joyful versus excited. Accordingly, when discussing affective response to exercise we will focus on *core affective valence*.

Another important aspect of our conceptualization of affective response to exercise has to do with timing. Studies assessing the way people feel before and after exercise generally support the conclusion that acute bouts of exercise improve affective states (Yeung, 1996). These findings appear to create a paradox as such positive affective responses to exercise should lead to high rates of exercise participation and adherence (Wininger, 2007). Yet, as we have discussed above, rates of regular exercise and overall PA are dismal (Tucker et al., 2011).

Hall et al. (2002) have pointed out that this apparent paradox can be explained by the fact that assessments of affect are often administered prior to and following, but not during the exercise task (for a review, see Ekkekakis and Petruzzello, 1999). According to learning theory, immediate consequences of behavior are more predictive of future behavior than delayed consequences (Neef et al., 1994). The subjective affective response experienced during exercise is more immediate than feelings experienced after the exercise has been completed, which may also include the affective response to completing exercise (Hall et al., 2002). Thus, when discussing affective response to exercise we will focus on core affective valence experienced *during* exercise rather than after exercise.

Finally, when considering affective *response* to exercise, it is critical to consider not just how people feel during exercise, but how their affect *changes* from *before* exercise to *during* exercise.

Following from the above arguments, we conceptualize affective response to exercise as *the shift in core affective valence from pre-exercise to during-exercise*.

AFFECTIVE RESPONSE TO EXERCISE AS A DETERMINANT OF EXERCISE ADHERENCE

The affect–adherence aspect of the posited exercise–affect–adherence pathway (**Figure 1**, path B) is consistent with psychological hedonism (aka the hedonic principle): people tend to pursue behaviors that lead to pleasure and avoid behaviors that lead to displeasure or pain. This basic principle of human behavior has been observed since the ancient Greeks (Usener, 1887/2010) and has been restated in the writings of Hobbes (1651/2008), Bentham (1789/2007), and Mill (1861/2012) and more recently in work by Young (1952), Cabanac (1992), and Kahneman et al. (1997) among others.

There is empirical evidence supporting the principle of psychological hedonism in the context of the exercise domain—i.e., the affect–adherence link. Recent studies have shown that affective responses recorded *during* individual exercise sessions at baseline and 6 months of an exercise promotion program were predictive of adherence to the exercise program 6 and 12 months later, even when controlling for ratings of perceived exertion (Williams et al., 2008, 2012). A recent review of studies showed similar findings, also highlighting that affective response *during* rather than immediately following exercise was predictive of future exercise behavior (Rhodes and Kates, 2015).

In addition to the handful of studies supporting the affect–adherence link in the context of exercise behavior, there is considerable evidence for the broader principle of psychological hedonism in research on other health-related behaviors, particularly addiction and eating behavior (Williams and Evans, 2014). Thus, the affect–adherence link (**Figure 1**, path B) in the posited exercise–affect–adherence pathway is not specific to the behavioral domain of exercise (i.e., domain-specific), but is instead consistent with the general principle of psychological hedonism that operates across behavioral domains. That is, the principle of psychological hedonism is *domain-general*.

As a domain-general principle, psychological hedonism—i.e., the tendency to pursue behaviors that lead to pleasure and avoid behaviors that lead to pain—has its own set of proximate and ultimate causes that go beyond the domain of exercise and thus beyond the scope of this paper. Numerous previous authors have written about the evolutionary underpinnings of psychological hedonism, as well as its proximate psychological and neurobiological mechanisms (e.g., Broom, 2001; Lemos, 2004; Panksepp, 2010). For an integration of proximate and ultimate causes of psychological hedonism in the context of health-related behavior, see Williams and Ruse (forthcoming).

AFFECTIVE RESPONSE TO EXERCISE: THE IMPORTANCE OF INTENSITY AND PERCEIVED UTILITY

We have thus far characterized affective response to exercise as "often negative" and claimed that many people dislike most types of exercise. Of course, the exercise–affect association is more nuanced than that. It is certainly true that many people dislike most types of physical exercise. But, *most* of us like at least *some* types of exercise. So what are the factors that cause someone to have a positive, negative, or indifferent affective response to exercise? And what is the potential functional significance of such affective responses? The answers to these questions are critical given the principle of psychological hedonism discussed above, the low rates of physical exercise in the general population, and the health consequences of an inactive lifestyle.

Just as an evolutionary approach was used to address the broader question of why many people avoid physical exercise, such an approach can be used to understand affective response to different types of exercise. To take this evolutionary approach it is necessary to consider what might be the functional significance of positive versus negative affective responses to different types of exercise, as well as the characteristics of different physical activities that would have made them adaptive to engage in during human evolutionary development.

Taking such an evolutionary perspective, we argue that the two factors that are most relevant to affective response to exercise are the intensity of the exercise and its perceived utility (**Figure 2**). This follows from our arguments that the evolved tendency to avoid physical exercise has to do with the functional significance of reducing *unnecessary* energy expenditure. Energy expenditure is, of course, a function of the intensity and duration of PA. And, the *necessity* of exercise, we will argue, is a function of its perceived immediate utility. Thus, we consider the negative affective response to *exercise* to be a manifestation of the more general tendency toward a negative affective response to *PA that is perceived to be unnecessary or of low utility*.

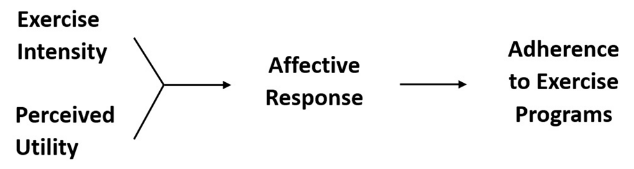

FIGURE 2 | Affective response as a function of exercise intensity and perceived utility.

Affective Response to Exercise of Different Intensities

From a functional perspective, intensity of exercise is critical because it determines energy expenditure over a fixed duration. In most classification systems, intensity of exercise refers to workload or energy expenditure per unit time, or physiological stress, such as percent of maximal heart rate or maximal oxygen consumption. However, Ekkekakis and colleagues (Ekkekakis, 2003; Ekkekakis et al., 2011) have argued that when examining affective response to exercise the most useful way to characterize exercise intensity is with respect to the ventilatory threshold (VT). The VT is the point at which the body transitions from anaerobic to aerobic metabolism and can be, albeit crudely, ascertained via the talk test: if you cannot carry on a conversation while exercising then you have exceeded the VT. More sophisticated assessment of the VT involves examination of expired air to determine the ratio of ventilation to oxygen consumption, which will begin to increase exponentially at the VT (Posner et al., 1987). Alternatively, blood lactate levels can be obtained to determine the lactate threshold, which generally coincides with the VT.

The reason that percentage of VT is a useful indicator of intensity when studying affective response to exercise is because the VT represents a transition point beyond which exercise cannot be maintained without disruption of homeostasis and severe bodily harm. That is, humans cannot engage in an all-out sprint for more than 100–200 m.

Using percent of VT as the indicator for exercise intensity, a pattern of findings is emerging in which:

(a) Exercise below the VT (e.g., slow walking) tends to result in a positive affective response,
(b) Exercise approaching but not exceeding the VT (e.g., brisk walking or, for some people, jogging) results in an affective response that varies from person to person and from one situation to the next, and
(c) Exercise exceeding the VT (e.g., jogging or, for some people, fast running or sprinting) that is continued for more than 10–20 s results in a nearly universal negative affective response (Ekkekakis et al., 2011).

According to the dual-mode model, there are two distinct psychobiological pathways—interoceptive and cognitive—that influence affective response to exercise (Ekkekakis, 2003; Ekkekakis and Acevedo, 2006). At exercise intensities above the VT, affective response is dependent on interoceptive cues that accompany the transition from aerobic to anaerobic metabolism. This includes feelings of fatigue and discomfort from accumulation of lactate and hydrogen ions as they dissociate from lactic acid, accelerated breakdown of creatine phosphate (McCann et al., 1995), the inhibition of glycolysis and glycogenolysis (Spriet et al., 1989), and the interference with the calcium triggering of muscle contractions (Favero et al., 1995). Because the physiological consequences of prolonged exercise exceeding the VT are universal among humans, the accompanying feelings of pain and displeasure in response to exercise of an intensity that exceeds the VT are also nearly universal (with the possible exception of individuals with congenital insensitivity to pain). This may be considered a specific case of the domain-general human tendency to experience pain resulting from tissue damage.

Thus, the functional significance of affective response to exercise exceeding the VT is relatively straight-forward and is explicitly stated in the context of the dual-mode model (Ekkekakis, 2009a,b). The negative affective response serves the function of providing a signal to decrease intensity or discontinue the exercise before serious bodily damage occurs (for a review, see Noakes, 2012).

But what can account for the variability in affective response to exercise approaching the VT? According to the dual-mode model, interoceptive factors play a lesser role in determining affective response to exercise that does not exceed the VT. Instead, when exercise intensity is approaching or below the VT then cognitive factors, such as perceived consequences of exercise, social norms, etc., play a larger role in determining affective response—i.e., the second "mode" in the dual mode model. Because there is greater variability among humans in these cognitive factors, the affective response to exercise that approaches but does not exceed the VT shows greater variability from person to person and in different situations.

The scant available research on cognitive determinants of affective response to exercise has thus far shown that social environment and self-efficacy are predictive of affective response to exercise of intensities approaching or below the VT (McAuley et al., 2000). These cognitive factors are important to understanding why some people may have a negative affective response to moderate intensity exercise, with implications for exercise promotion interventions. However, we propose that greater understanding of the variability in affective response to exercise that does not exceed the VT can be achieved by taking an evolutionary perspective. Specifically, we posit perceived utility as an important cognitive mechanism that determines affective response to exercise (**Figure 2**).

Perceived Utility as a Determinant of Affective Response to Exercise

What determines affective response to exercise that is below or approaching the VT? This question has immense public health implications. If we can understand when and why people have a negative affective response to exercise, then we can develop interventions to promote more positive affective responses to exercise and thus make exercise adherence more likely.

One of the problems with intentional exercise as a form of PA is that it often has no immediate purpose other than to expend energy. Although energy expenditure, for its own sake, has positive long-term health consequences in most modern environments, it was not adaptive throughout the vast majority of evolutionary history stretching back to human hunter/gatherers, protohumans, and beyond (Gluckman and Hanson, 2008). Although some types of exercise, such as sports, may serve an additional purpose, many types of exercise, such as running on a treadmill or walking around a track, exemplify PA that would have been unnecessary and thus maladaptive in ancestral times (Lieberman, 2015). Moreover, the health benefits of PA in modern environments are indirect and temporally distal.

The perception that physical exertion serves some *immediate* purpose may be a key factor in determining affective response to exercise. Indeed, earlier we argued that energy expenditure was maladaptive *except when it was necessary to obtain food, avoid predators, engage in reproductive behavior, or engage in other important social activities.* Thus, an important cognitive factor that may influence affective response to physical exertion is the *perceived immediate utility of PA*.

Perceived utility may operate through both reflective and automatic pathways consistent with dual-processing models (Evans, 2008; Williams and Evans, 2014). The reflective sense of perceived utility comes from conscious consideration of the immediate outcome or goal of the PA. Thus, physical activities that have a clear and immediate purpose or goal, such as walking or biking for transportation, may result in a more positive affective response than walking or biking for no immediate purpose (**Figure 2**).

The automatic sense of purpose may result in performance of physical activities that mimic behaviors that would have served an immediate adaptive purpose among our evolutionary ancestors, even if such behaviors have no functional purpose in the here-and-now. For example, many leisure sports (e.g., rugby, soccer, basketball) and play behaviors (e.g., tag) involve chasing a ball or chasing or fleeing from an opponent, which mimic the chasing and fleeing behaviors necessary for survival in ancestral environments. Such physical activities may be more likely to result in positive affective responses than physical activities that lack these qualities (Jackson and Csikszentmihalyi, 1999; Chen et al., 2001). This automatic sense of purpose and its effects on action is consistent with the affordance-competition model in which action-selection is integrated with, rather than preceded by, conscious decision-making (Cisek, 2007; Cisek and Kalaska, 2010; Smits et al., 2014).

Perceived Utility, Exercise Intensity, and Affective Response to Exercise

Perceived utility may have a dimensional quality that interacts with exercise intensity to influence affective response to exercise (**Figure 2**).

We hypothesize that when perceived utility is at the extreme low end, affective response to exercise will be negative regardless of exercise intensity. The available evidence suggests that humans tend to have a positive affective response to exercise that is below the VT. However, from an evolutionary perspective, prolonged exercise—even if well below the VT—still results in energy expenditure and thus may still have been maladaptive among human evolutionary ancestors particularly if it had no adaptive function and was continued for a significant duration. It follows that a negative affective response even to light intensity physical exertion may still occur when the exertion serves no other purpose. For example, to get up and change the channel on the television, take the stairs, or park far away when there is no reason not to simply use a remote control, take the elevator, or find a close parking spot. That is, people may universally respond positively to light intensity exercise as long as they perceive that it has some immediate utility.

When perceived utility is at the extreme high end, affective response may be positive—at least for brief periods—even when exercise intensity exceeds the VT. For example, while maximal exertion typically results in a negative affective response, such negative responses may be blunted if someone is sprinting to get on a bus that is about to leave. Likewise, affective response to maximal exertion is likely to be more positive in the context of team sports or running competitions.

In the middle range of the dimension, perceived utility may be enough to result in a positive affective response depending on the intensity of the exercise. Thus, at very low intensities even a meager perception of utility may lead to a positive affective response. For example, it is possible that complying with a researcher's request provides enough of a purpose for engaging in light intensity exercise to turn what might otherwise be a negative affective response to a light intensity exercise into a positive affective response. However, affective response to exercise at higher intensities is likely to be negative if perceived utility is modest.

This conceptualization of the interaction between perceived utility and PA intensity is consistent with the dual-mode model in that perceived utility is a cognitive factor that plays a larger role when exercise intensity does not exceed the VT.

IMPLICATIONS

One of the main points of the present paper is that the human tendency to have a negative affective response to PA that has no immediate utility—including many types of intentional exercise—is an innate tendency that is likely universal among humans. Likewise, the tendency to avoid PA that results in a negative affective response is consistent with the domain-general innate human tendency to pursue behaviors that lead to pleasure and avoid behaviors that lead to pain or discomfort.

The fact that these tendencies—which together represent the exercise–affect–adherence pathway—are innate does not mean that they are unchangeable. Indeed, humans can make conscious decisions about their behavior and thus are capable of overcoming even the strongest innate behavioral tendencies. Nonetheless, strong innate behavioral tendencies are *difficult* to overcome. Thus, it may be difficult to attempt to change the human tendency to dislike PA that has no immediate utility or the human tendency to avoid PA that has previously resulted in a negative affective response.

Instead, we propose an approach based on an evolutionary functional perspective: to (a) promote exercise and other physical activities that are perceived to have an immediate purpose, or (b) attempt to instill greater perceived purpose for a wider range of physical activities. We posit that these strategies are more likely to result in more positive (or at least less negative) affective responses to exercise, better adherence to exercise programs, and higher rates of overall PA.

One general strategy for improving adherence to exercise programs is to promote physical activities that are already perceived to have an immediate purpose, as these activities are more likely to result in a positive affective response and thus improved adherence. This may include increasing activities such as walking or cycling for transportation, or relying on gardening for producing fresh fruits and vegetables. Other examples may include promoting activities that mimic the once necessary activities of hunting (chasing) prey and escaping (fleeing) predators. For example, many leisure sports (e.g., rugby, soccer, basketball) and play behaviors (e.g., tag) involve chasing and/or fleeing and chasing and fleeing leisure activities are observed in both Eastern and Western history as well as in the present-day (Mechikoff and Estes, 2006). Other examples include interactive video games like Wi, Pokemon Go, etc. We hypothesize that these activities will result in a more positive affective response than activities of the same intensity that do not have the fleeing, chasing, or social bonding characteristics.

A second general strategy is to modify activities so that they have an immediate purpose. Perhaps the most relevant application of this idea is the use of financial incentives to increase exercise behavior. Consistent with behavioral economics theory (Kahneman, 2003), use of financial incentives provides an immediate purpose for physical exercise when there is no other functional purpose and given that the health benefits of exercise are uncertain and distal. Theoretically based concerns that financial incentives may undermine intrinsic motivation (Deci et al., 1999; Frey and Jegen, 2001) have largely been dispelled by consistent data showing that in most situations financial incentives complement rather than undermine intrinsic motivation (Cerasoli et al., 2014; Shaw and Gupta, 2015). Moreover, the undermining of intrinsic motivation is irrelevant for most health-related behaviors, including exercise, for which there is low baseline intrinsic motivation (Promberger and Marteau, 2013). Indeed, a recent systematic review shows preliminary support for the use of monetary incentives to increase exercise behavior (Strohacker et al., 2014).

LIMITATIONS

Is This a "Just-so Story"?

Although an evolutionary perspective may open up new avenues to thinking about the exercise–affect–adherence relationship, an inherent weakness is that hypotheses regarding functional significance are difficult to test empirically. It is impossible to recreate the ancestral environments in which the exercise–affect–adherence relationship evolved. While it *is* possible to generate hypotheses that are logically *consistent with* what we currently know about the exercise–affect–adherence relationship, as well as educated guesses about the nature of ancestral environments, a *post hoc* explanation that fits the existing data falls well short of an *a priori* hypothesis in terms of scientific viability.

It is for this reason that *post hoc* hypotheses about the evolution of modern traits are often referred to by skeptics as "just-so stories" (Gould and Lewontin, 1979; Kipling, 2013). For example, we may conjecture *post hoc* that the giraffe has a long neck because those giraffes born with long necks were more likely to reach the top-most leaves on trees and thus more likely to survive in times of drought and pass the long-neck genetic predisposition to their offspring. However, other explanations also fit the data and thus are just as viable. Perhaps giraffes evolved long necks because it allowed them to spot predators from far away, or long necks could have evolved as a weapon in intraspecies sparring matches, or as a sexual selection characteristic. The sparse available evidence points to the first of these alternative explanations (Cameron and du Toit, 2007), but is hardly conclusive.

Similarly, we may generate alternative explanations for the evolution of the exercise–affect–adherence relationship. For example, a viable alternative explanation for the negative affective response to exercise that approaches the VT—instead of positing an energy conserving function—is that such a response is due to the effects of evaluative conditioning. That is, exercise that approaches the VT often immediately precedes exercise that exceeds the VT, which, for reasons discussed above, automatically results in a negative affective response, presumably because of the immediate dangers of acute overexertion. Thus, exercise that approaches the VT (the conditioned stimulus) may come to elicit a negative affective response (the conditioned response) because it has become associated with exercise that exceeds the VT (the unconditioned stimulus), which reliably leads to a negative affective response (the unconditioned response). Though speculative, our point here is simply to illustrate how one can easily generate *post hoc* alternative hypotheses.

Given this, how can we produce evidence in support of our evolutionarily informed hypothesis regarding the functional significance of the negative affective response to moderate intensity exercise? Multiple authors have devised schemes for overcoming this problem (Cosmides and Tooby, 1987; Laland and Brown, 2011). Most important is that a posteriori evolutionary hypotheses (or theories) must be useful for generating *a priori* hypotheses and, when relevant, guiding practical interventions.

Our a posteriori hypothesis about the functional significance of a negative affective response to exercise and the role of perceived utility, like all scientific hypotheses, cannot be proven beyond all doubt. However, the evolutionary perspective we have outlined herein is useful for formulating *a priori* hypotheses about what sort of physical activities will result in more positive affective responses as well as what intervention strategies are likely to lead to improved adherence to exercise promotion programs. To the extent that these hypotheses are supported the overarching a posteriori evolutionary hypothesis also gains support.

Dangers of a Misunderstood Evolutionary Approach

Applications of Darwinian evolutionary ideas can lead to defiance and outrage if misinterpreted. Thus, let us be clear. We are *not* suggesting that because most (if not all) humans have a genetic predisposition toward negative affective response to unnecessary PA that we are *predestined* to be physically inactive. Human (and all other animal) behavior is a function of the *interaction* between genetic predispositions *and* environmental conditions. Indeed, this is a main point of our thesis: it is only because of human-engineered changes in our environmental conditions (i.e., it is no longer necessary for us to work for our food) that our predisposition to avoid unnecessary physical exertion has become a liability. Thus, it is well within our capabilities to reengineer our environments to once again make PA necessary or, at least, to serve an immediate functional purpose.

Likewise, we are *not* suggesting that the tendency toward negative affective response to exercise is the *only* reason for the low rates of PA in the general population. There are other reasons why some people do not engage in regular exercise. For example, lack of access to safe and affordable places to exercise is a common barrier (Walsh et al., 1999), and some people anticipate feeling embarrassed or lack the social support to engage in physical activities (Anderson et al., 2006; Grieser et al., 2006). These alternative reasons for the low rates of exercise complement rather than compete with our evolutionary hypothesis.

CONCLUSION

Despite our unique ability among animal species to significantly modify our environment, we humans are still members of the animal kingdom. We share with all animal species the genetically engrained tendency to be efficient when it comes to expending energy.

We hypothesized herein that negative affective response to exercise, particularly exercise that approaches or exceeds the VT, is an adaptive psychological mechanism that evolved because—in combination with the domain general tendency to avoid displeasure and pain—it minimized unnecessary PA among our evolutionary ancestors. Nonetheless, our ancestors needed to act when there was an immediate and compelling purpose, such as when obtaining food, fleeing from predators, or engaging in social bonding and reproduction. Thus, we further hypothesized that affective response to exercise, and other forms of PA, will be more positive when the perceived immediate utility of the PA is high.

In today's environment, the human tendency to have a negative affective response to unnecessary physical exertion is directly responsible for the difficulty adhering to exercise programs and the corresponding low rates of PA in the general population. Although we no longer live in conditions that require us to expend energy to achieve basic survival needs, we can create conditions under which physical exertion is perceived to have an immediate purpose. This can be accomplished either by promoting activities that have an inherent utility (e.g., walking for transportation) or that mimic activities that served a purpose in ancestral environments (e.g., sports and games that involve chasing and fleeing), or by artificially providing an immediate utility for exercise (e.g., via monetary incentives).

AUTHOR CONTRIBUTIONS

HL conceived of the hypothesis with input from DW and JE. HL and JE wrote an early draft of the manuscript. DW revised and completed the writing of the manuscript. All authors read and approved the final manuscript.

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Exercising for the Pleasure and for the Pain of It: The Implications of Different Forms of Hedonistic Thinking in Theories of Physical Activity Behavior

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"They [pleasure and pain] govern us in all we do, in all we say, in all we think" (Bentham, 1780, p.1)

Physical inactivity is one of the most widely reported risk-factors associated with many non-communicable diseases, including cardiovascular disease, diabetes mellitus, cancer, obesity, hypertension, stroke, osteoporosis, and depression (Warburton et al., 2006; Bravata et al., 2007), as well as overall global mortality (World Health Organization, 2010). Interventions that increase physical activity can reliably reduce the impact of these undesired outcomes. However, the key question facing research and theory is how best to conceptualize the associated psychological factors, which ultimately determine adherence to behavioral change. Social-Cognitive models of behavior, including the Theory of Planned Behavior, Transtheoretical Model, and Social-Cognitive Theory, represent popular explanatory frameworks, which can help practitioners understand how best to improve physical activity behavior.

In recent years, however, the usefulness of these models has been questioned. Research shows social-cognitive models typically only account for approximately 25% of the variation in exercise and physical activity behavior, which limits the effectiveness of related interventions (Ekkekakis and Dafermos, 2012). Instead, exercise behavior may be better understood by looking beyond the purely cognitive and social components. Recent research demonstrates affective components can predict physical activity behavior. For example, Williams et al. (2008) found affective responses to acute moderate-intensity exercise predicted subsequent physical activity levels in sedentary adults between 6 and 12 months later. These findings, which have been replicated (e.g., Kwan and Bryan, 2010), suggest interventions that manipulate the affective response to physical activity could improve long-term physical activity behavior.

A growing body of literature now promotes affective models, and their synthesis with social-cognitive theories (Kiviniemi et al., 2007; Calitri et al., 2009; Lawton et al., 2009). Within some of these accounts (Williams et al., 2008; Nasuti and Rhodes, 2013), the term "hedonism," which refers to a theory of human motivation in which individuals are motivated to experience pleasure and avoid pain, is being increasingly used to explain the predictive utility of these affective components (Ekkekakis and Dafermos, 2012). For instance, Williams et al. (2008) argues for "hedonic theory to [focus] on affective responses to behavior" (p. 232), while Cabanac (2006) asks whether the "...hedonic dimension of perception is what motivates and optimizes behavior..." (p. 111). Indeed, Ekkekakis and Dafermos (2012) declare "the foundation has now been laid for the development of a hedonic theory of exercise behavior" (p. 325). Despite this trend, there is a general failure in both the physical activity and psychology literature (in the round), to define what is *actually* meant when referencing to hedonism *per se*. Thus, the aim of this article is to first discuss the definitional problems associated with hedonism, and then briefly explore how the lack of clarity therein has hindered the development of modern affective accounts of adherence to physical activity. We hope this discourse will ultimately aid theorists and practitioners alike who seek to understand adherence better, in terms of the related affective states.

In psychology hedonism typically refers to the assumption that an individual will normally "...approach pleasure and avoid pain..." (Higgins, 1997, p. 1280), or when "...pleasure seeking is the *main* motivator of human behavior" (emphasis added, Veenhoven, 2003, p. 437). At first glance, these definitions indicate that while both the pursuit of pain and avoidance of pleasure are important drivers of behavior, other motivators can legitimately contribute their "votes" toward biasing subsequent actions. Upon closer inspection, however, a more extreme version of hedonism also exists in the literature. For instance, Sober and Wilson (1999) argue that in psychological hedonism "avoiding pain and attaining pleasure are the only ultimate motives that people have; everything else that we want, we want solely as a means to achieving those twin ends" (p. 2). Similarly, Vroom (1964) suggested hedonism's central assumption is that: "In every situation people select from alternative possibilities the course of action which they think will maximize their pleasure and minimize their pain" (p. 9). Finally, Mees and Schmitt (2008) argued that the principle postulate of classical hedonistic motivational theory is that "actions are ultimately carried out to maximize the level of one's own pleasure and to minimize one's own pain" (p. 157).

Hedonism can thus be defined in a most extreme sense, in which no other motivational drivers exist beyond *the pursuit of pleasure and avoidance of pain* [hereon referred to as Ultimate Psychological Hedonism (UPH); (Mees and Schmitt, 2008)]. Therefore, when developing modern theories of motivation for physical activity it is crucial to delineate between UPH and its less extreme counterpart [Partial Psychological Hedonism (PPH)], which can accommodate alternative motivational drivers. Indeed, such confusion is evident in Weiner's (1992) work, where hedonism is defined as "a utilitarian doctrine [which] asserts that pleasure and happiness are the chief goals in life" (p. 29). Since this statement invites the possibility of other motivational drivers, which sub-serve this "chief" goal, it is unclear if this definition invokes either UPH or PPH. In contrast, Weiner (1992) later states that "the single principle on which most theories of motivation agree is that persons seek to maximize pleasure and to minimize pain, with motivation derived from this *fundamental law*" (emphasis added, p. 353). Following his brief critique of hedonism's validity as a theory of human motivation, Weiner (1992) also states "If humans do not always act as hedonic maximizers, then other motivational principles are needed" (p. 357). Moreover, when Higgins (1997) states: hedonism refers to the idea that individuals "approach pleasure and avoid pain" (p. 1280), and that hedonism "...is the basic motivational assumption across all areas of psychology..." (p. 1280), it appears easy to conflate these two forms of hedonism.

Thus, with the rapid growth in popularity of hedonistic-referenced affective accounts, we strongly recommend that future models in physical activity behavior account for these different hedonistic perspectives, and clearly define the version they refer to. While these inaccuracies may seem trivial, there may be important unintended consequences of misrepresenting hedonism in motivational theory. Primarily, we argue the main problem is that unclear definitions prevent academics from effectively challenging theoretical components. If authors argue that UPH underpins a particular theory, then key aspects of the UPH component can be contested. For instance, UPH is widely considered as unfalsifiable, which is empirically problematic for a theoretical model (Vroom, 1964; Locke, 1975; Steers et al., 2004). Moreover, serious logical corollaries may also be unnecessarily invoked. For instance, inadvertently adopting UPH rather than PPH implies an acknowledgment that human nature is purely deterministic, wherein humans have no free will to behave outside of their affective confines. Thus, the individual who passionately "gives themselves to the cause," or behaves "out of principle," would only be deemed to be altruistic or morally virtuous in terms of their effort to obtain the underlying pleasure or pain avoidance for them self alone. This approach would radically transform how many lay people view human nature, toward a self-centered or self-serving perspective (Nahmias et al., 2005; Baumeister, 2008; Sarkissian et al., 2010).

As Locke (1975) states, determinism "wipes out the possibility of ethics" (p. 462), leading UPH to be controversial at best, and morally repulsive at worst (Timmermann, 2005). On top of this, a deterministic view of human nature may also unnecessarily conflict with distal aspects of motivational theory, which are incompatible with determinism. For example, Self-Determination Theory (SDT) is inherently humanistic in its focus, with its emphasis on the growth of human potentials (Ryan et al., 2008). Yet, if SDT's hedonistic components are vague in definition, or if this theory overlooks different hedonistic perspectives, as is the case in one such article (Ryan et al., 2008), viewing SDT through a deterministic lens, in which individuals are inherently selfish, causes inherent conflict.

Mistakenly implicating UPH rather than PPH is likely to negatively impact the coherence of a theory or framework. Articles detailing Approach-Avoidance Motivation (AAM), for instance, often present hedonism as the intellectual basis of their framework (Elliot, 2006). However, Elliot (2006) also states: "Self-conceptions, implicit theories, attachment schemas, environmental affordance, cultural values and norms" (p. 114) can underpin goal-directed behavior. However he does this without explicitly delineating if such determinants, which would presumably be lower down in the hierarchy of needs, are simply a further means to obtain pleasure or reduce pain. Moreover, Higgins (1997) states hedonism to be "the basic motivational assumption of theories across all areas of psychology, including theories of emotion in psychobiology, conditioning in animal learning, decision making in cognitive and organizational psychology, consistency in social psychology, and achievement motivation in personality" (p. 1280). Yet Higgins (1997) appears to refer to PPH and not UPH, despite the fact Vroom (1964) and others (Locke, 1975; Steers et al., 2004) argue UPH is unfalsifiable and therefore empirically redundant.

Confronting this definitional issue is essential, and can be achieved within the physical activity literature by taking a few important steps. Firstly, making oneself aware of the different forms of hedonism that exist, and the consequential logical corollaries that may be implicated, is an essential precaution when operating in a field with inherent definitional challenges (Ekkekakis and Petruzzello, 2000). This increased awareness will promote the sensitivity in which hedonistic terms are used, and ensure the definitional problems that have occurred in other domains are prevented from developing. Secondly, if there is any chance of miss-representation of hedonistic terms, we advise authors to make explicit what they mean, rather than opting for brevity. Indeed, clearly discounting UPH in a text is preferable if there is potential for it to be implicated without intention.

To conclude, the future is promising for physical activity research. The field is moving away from models that exclusively account for social or cognitive components, and toward models that additionally account for affective components. However, the indiscriminant use of hedonistic terms in different areas of psychology and philosophy has hindered the ability to accurately determine which version of hedonism is actually intended. The aim of this article is to bring attention to the indiscriminate use of hedonistic terms, and highlight the consequential effects of such actions. It is hoped the physical activity literature will benefit from being better equipped, so as to use hedonistic terms more appropriately for the development of more refined theoretical models of behavior.

AUTHOR CONTRIBUTIONS

SM conceived of the main argument and rationale for the paper during his Masters degree, under the supervision of DE. SM and DE developed and wrote the paper together and both authors approved revisions for journal submission.

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A Qualitative Analysis of Emotional Facilitators in Exercise

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Although previous research has shown that emotions are consistently associated with sport and exercise behavior, the working mechanisms are not understood to the extent of creating an intervention. The aim of this study is to identify situations and aspects of recreational sport and exercise, which lead to positive emotional reactions in people taking part in regular and long-term exercise. In this study, 24 adults (12 female, 12 male) distributed over three age groups (young, middle, and late adulthood), took part in recreational sports (individual or team sport) for at least 5 years. Semi-structured in depth interviews with questions about sport and exercise habits, long term participation and emotional response in a sporting environment were conducted in order to ascertain those situations and aspects of the exercise program triggering positive emotions. Interviews were transcribed verbatim and followed Grounded Theory principles. Emerging concepts were grouped and merged into different categories representing the key aspects of sport and exercise. Four factors were identified which are associated with the emergence of positive emotions in recreational sport and exercise. Firstly, perceived competence is one of the major factors influencing emotions during exercise and can represent individual and collective success and progress, competition and challenge. Secondly, perceived social interaction is another factor comprising of all sorts of peer-related aspects such as communication with others, being part of a group and creating close relationships or friendships. Thirdly, novelty experience in contrast to other none-sporting activities such as work, family or other leisure activities was another factor. The last factor found was the perceived physical exertion comprising of the degree of exhaustion, a possibly delayed turnaround in the emotional response and the aspect of sport being a physical compensation for everyday sedentary life. The results of this study provide the starting point for the development of interventions to enhance positive emotions in sports in order to increase maintenance and adherence to recreational sport and exercise.

Keywords: emotions, grounded theory, exercise maintenance, perceived competence, belongingness, novelty experience, exercise intensity

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INTRODUCTION

Evidence shows a wide range of health benefits from exercise and physical activity (Paffenbarger et al., 1993; Mensink, 2003; Rütten et al., 2005; Krug et al., 2013; Reiner et al., 2013), but also poor compliance and adherence to exercise programs (Mensink, 2003; Ekkekakis and Lind, 2006; World Health Organization [WHO], 2010; Krug et al., 2013; Eurobarometer, 2014). These health improvements only persist due to regular participation in physical activity and exercise whereas a significant decline or drop out causes a decrease or complete loss of initially gained benefits (Mujika and Padilla, 2000a,b). Regardless of people knowing this necessity to continue exercising, the majority of the population remains physically inactive even those who are younger (Jekauc et al., 2012). Furthermore, empirical evidence has identified high dropout rates of up to 50% in exercise programs, within the first 6 months (Dishman and Buckworth, 1996; Annesi, 2003) and a common relapse to lower or no levels of activity after the exercise program has finished (Amireault et al., 2013). Effort has been made to encourage behavior change (Biddle et al., 2012) with marginal success (Rhodes and Pfaeffli, 2010). Even though insights about the motivational process of initiation of physical activity and exercise is advanced, there is a paucity of research which investigates the maintenance of such activities (McAuley et al., 2007; van Stralen et al., 2009; Kwasnicka et al., 2016) as well as a lack of effective practice (Amireault et al., 2013). Previous research indicates that the initiation of physical activity and exercise has different influences (e.g., strategic planning and recovery self-efficacy; Schwarzer et al., 2007) in comparison to the maintenance (habit, environmental, and social influences; Kwasnicka et al., 2016) of it (see also Biddle and Mutrie, 2008). Therefore there is a high interest in identifying key factors which affect physical activity and exercise maintenance such as specific facilitators (Amireault et al., 2013). Although recent findings support the notion of facilitators which foster behavior maintenance (previous physical activity habits, positive attitude, expectations; Amireault et al., 2013; perception of competence, social affiliation, environmental conditions, sense of autonomy, specific physical activity; Rhodes and Kates, 2015), the capability of established theoretical frameworks is fairly limited (Rhodes and Pfaeffli, 2010; Amireault et al., 2013). Indeed, most factors are based on cognition, but established cognitive theories and models can only explain parts of people's behavior (Jekauc et al., 2015; Kwasnicka et al., 2016) revealing a lack of theoretical foundation. Perhaps diverting attention to other domains such as facilitators of emotions in the context of sport and exercise is more promising (Williams, 2008; Rhodes and Kates, 2015) and may lead to a better understanding, which despite years of research is still limited (Rhodes et al., 2009).

To succeed using this approach a clear definition is crucial to distinguish between different terms and constructs used (Tuson and Sinyor, 1993). According to Caspersen et al. (1985) *"physical activity is defined as any bodily movement produced by skeletal muscles that results in energy expenditure" [. . .]* which *"can be categorized into occupational, sports, conditioning, household, or other activities"* (p. 126). Instead, sport and exercise are subcategories of physical activity, which are often planned, structured, and repetitive with the purpose of improving or maintaining physical capability (Caspersen et al., 1985). Since sport and exercise are subsets of physical activity, evidence drawn from sport or exercise might be valid for each other and broadly for physical activity but not the other way round. Following the approach from Buckworth et al. (2013), this article is mostly focused on exercise because the majority of researchers used methods that fit the definition of exercise mentioned above, to measure physical activity. Since classic competitive sports are expected to have a specific emotional pattern (e.g., influenced by a higher goal orientation or different expectations such as external rewards), a look at recreational sports might result in a broader insight.

The same procedure is required for the differentiation of affects and emotions. According to Russell and Feldman Barrett (2009) the *core affect* (because it is considered to be basic or irreducible; Ekkekakis, 2003) is characterized as a "*neurophysiological state consciously accessible as a simple primitive non-reflective feeling most evident in [. . .] emotion but always available to consciousness*" (p. 104) such as pleasure and displeasure, tension and relaxation, or energy and tiredness (Ekkekakis, 2012). Core affect can occur on its own or as a part of emotion, e.g., like pride which is feeling good about oneself whereas '*feeling good*' represents the core affect and '*about oneself*' the other, cognitive, component (Russell, 2003). Thus emotions are a kind of affective state, but they do not apply vice versa. Making reference to Russell and Barrett (1999) and Ekkekakis (2012) simplifies the definition of emotions that are elicited by and are a reaction to and about a certain stimulus, with its cognitive appraisal involved as an elemental characteristic and reveals a more complex phenomenon in comparison to basic affect (Ekkekakis and Petruzzello, 2000). The previously mentioned example of 'pride' represents an emotion which includes all these criteria mentioned before and demonstrates the close relation between the two concepts of affect and emotion. In this article, the focus is primarily on emotions and not affects not only due to the qualitative design of the study.

The aim of the present study is to identify facilitators which affect the emotional response to recreational sport and exercise and thus the maintenance of both. Research about the role of emotions in relation to sport and exercise or facilitators is sparse (Rhodes and Kates, 2015) and the few models that exist focus on leisure time activities that seek pleasure, enjoyment, and fun (Rhodes et al., 2009). Positive affects are one of the fundamental basics in order to understand the nature of enjoyment (Scanlan and Simons, 1992) which in turn reinforce behavior (Rhodes and Kates, 2015; Kwasnicka et al., 2016) and enhance participation and maintenance in sport and exercise (Stenseng et al., 2015). Thus facilitators for positive emotion during exercise must be identified to prompt the development of interventions charged with stimuli which affect one or more facilitators to ensure that each individual experiences positive emotion (for details see the results section below; Scanlan and Simons, 1992).

MATERIALS AND METHODS

A qualitative study was conducted to identify facilitators that affect the emotional response to recreational sport and exercise.

Participants

In order to ensure heterogeneity of the sample the participants were evenly recruited across three factors: age, sex, and type of exercise. Age was divided in three age categories: 18–34 years (AG1), 35–59 years (AG2) and older than 60 years (AG3). Sex (male vs. female) and type of exercise (group vs. individual) consisted of two categories. Combining these three factors (3 × 2 × 2) 12 cells emerged. For each cell, two participants were recruited. Thus, the sample consisted of 24 participants. All participants took voluntarily part in this study and were recruited in Berlin as native German speakers. Ethical approval for the study was provided by the Humboldt University and all participants signed an informed consent form at the beginning of the study.

Participants were involved in formal recreational sports such as soccer, volleyball, or swimming and informal recreational sports like climbing, martial arts, or paddling; organized in sport clubs, training groups, or exercising on their own. None of the participants were a high-level-competitive or professional athlete or worked in a job that involved sport. All participants described their actual level of engagement in popular sports as more or less ambitious. The average training frequency was three times a week (mean: 2,98; $SD = 1,84$) and the duration was around 90 min (mean: 94,04; $SD = 34,42$). Compared to their age, participants reported an involvement in recreational sports of around 70% of their lifespan (e.g., age of 28 and 22 years of sport participation results in 78, 57% of engagement; mean: 69,89; $SD = 22,77$) with a minimum of 6 years engagement. Of the 24 participants, there were even 12 that took part in competitions (e.g., league game or small tournament), five participated in competitions previously and seven had never participated in any competitions.

Data Collection

Students of Sport Science of the Humboldt University of Berlin through acquaintances or friends recruited suitable participants without any deeper relationship to the interviewer. At the start of each interview, relevant information about the study, the procedure and the data usage were given to the participants which had agreed to be interviewed and recorded. Data collection was made via voluntary, non-directive, face to face interviews, which where standardized using a semi-structure interview manual according to Tong et al. (2007) which refers to a gradual three level approach (three types of questions from the general to the specific) in a quiet environment. Participants were asked open-ended-questions about their experiences, habits, and emotions in the context of sport and exercise. Firstly, questions remained general in order to be able to get to know the participant, e.g., "*How did you get into sport and exercise?*" "*What is your first memory in the context of sport and exercise?*" "*Which of these kind of sports/or what kind of exercise do you do regularly?*" The second step was to ask about their habits and how they emerged. *"What significance does regular exercise have in your everyday life?" "How much do you have to think about deciding whether to exercise?" "If you decide not to exercise, could you describe the inner monolog with yourself any further?" "Would you miss something after quitting your sport/exercise?"* The final part of the interview contained questions especially about emotions within exercise and sport: *"What kind of feelings do you experience whilst you exercise?" "In which kind of situation do you experience the most enjoyment?" "How significant is the experience of pleasure to you, to be able to keep on exercising?"*

In addition to the participant and the interviewer, a third person attended to write minutes of the interview, which lasted approximately 20–40 min. Referring to GAT ("Conversation Analytic Transcription System"; Selting et al., 2009) the interviews where transcribed verbatim.

Data Analysis

Verbatim transcripts of the audio recordings were used in content analysis related to the Grounded Theory (Strauss and Corbin, 1996). The first step was the open encoding of the full text of the whole 24 interviews. Therefore the interviews were read completely by three different independent researchers and thoughts were written down in memorandum. Relevant information was grouped into different concepts. This working phase was done independently by two researchers, who met for a weekly meeting to compare and to discuss their findings and stayed as close as possible to the script in order to avoid bias. All concepts were grouped within categories (e.g., performance, process, achievement, competition, and challenge in the context of positive emotions were summarized in the category*perceived competence* (*PC*; **Figure 1**) and were checked for connections between each other in the axial encoding process. In that second step categories that seemed synonymous were merged into one so that only the varying categories remained [e.g., categories such as *closeness to nature* and *curiosity and otherness* were merged into *novelty experience* (*NE*)]. The last working step was selective coding to ensure the integrity of the four categories by searching for appropriate concepts and by analyzing the context in which they were mentioned. The final data was organized accordingly into categories and subcategories in order to be able to formulate the theory that is the focus of this study.

RESULTS

The majority of participants (22 out of 24) with their long lasting engagement in recreational sports and exercise referred to positive emotions related to this activity. For a better understanding, it is crucial to discover facilitators for these positive emotions to increase sport and exercise involvement and its maintenance. Four different factors with a high to moderate impact on the emotional experience could be revealed (**Figure 2**). The strongest and the most frequently mentioned concepts refer to the category *PC* which was mentioned in 22 out of 24 interviews. The second conceptual group was related to *perceived social interaction (PSI),* which was mentioned in 19 out of 24 interviews. The third group was related to NE and was mentioned in 18 out of 24 interviews. Lastly, the physical dimension *perceived physical exertion (PPE)* was found in 14 out of 24 interviews. Whereas three of these facilitators are psychological, one is also affected by interoceptive signals. According to the three independent factors (sex, age, and

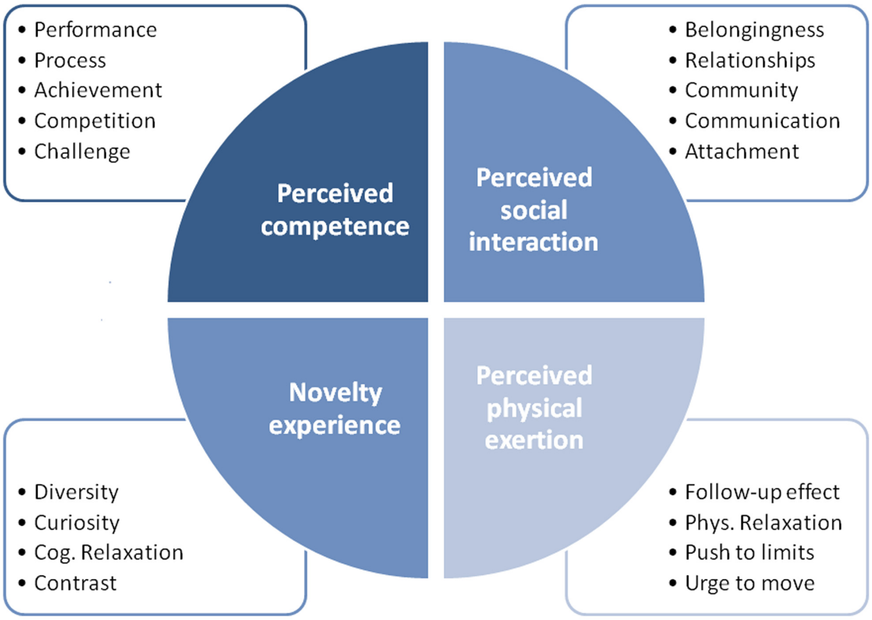

FIGURE 1 | Concepts which form each of the four categories.

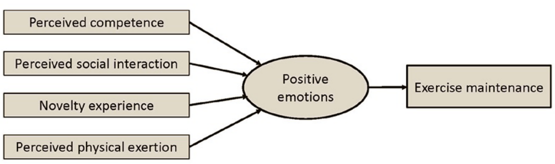

FIGURE 2 | Facilitators of positive emotions in a sporting environment.

sport type) some differences have occurred as discussed below (**Table 1**).

Perceived Competence

Firstly, PC was found to be the most influential factor in the emotional experience in recreational sport and exercise, -feeling competent and capable was often combined with positive emotions. PC represents the own individual sense of how well one is performing in a particular situation in relation to exercise, in the present, retrospectively or in the future. Whilst performing well during a task, being successful or winning a game, mastering a challenge, achieving a goal or making progress created positive emotions in all participants such as pleasure and enjoyment; there was also often excitement or pride:

> *"When I think back to how we won the championship I remember being happy for weeks"; "It is simply awesome when you are allowed to shoot the free kick and are able to fool the wall–I always really look forward to doing that"; "If something really cool worked out, then you are very happy about it. Sometimes you are also proud when you are making progress. After our tournament I was proud of my good results."*

Perceived competence is not only binding on the individual performance; collective accomplishments were also perceived and evaluated:

> *"If you manage to score or prevent a good move being successful or if you see a good move which you saw 30 years ago done by somebody and he replicates that and you comment "hey you didn't forget that." These sorts of things makes you happy or happy for the others"; "I am also happy for my teammates when they are doing well and sometimes even when the opponents do something great."*

Only two participants did not refer to any concepts concerning PC as a facilitator for enjoyment and pleasure in recreational sport and exercise. Furthermore there were no cues among the interviews for a negative emotional response to PC or a positive response to a lack of PC. Also sex did not have an impact on PC among the interviews. Men and women mentioned PC in the context of positive emotions equally (both 11 out of 12 interviews). The same result was shown in the individual and team-sport participants (both 11 out of 12). Only the age factor showed a very small variation. In AG1 everybody mentioned concepts related to PC. In both other groups (AG2 and AG3) only seven out of eight mentioned PC as a factor related to pleasure and enjoyment.

Perceived Social Interaction

Secondly, PSI is another important factor that influences emotional experience in a sport and exercise-related environment and was mentioned in 19 out of 24 interviews. Many participants appreciate the company of others in the context of recreational sport or during exercise. To have social bonds with others or exercise with them triggers positive emotions, whereas being on your own does not (in category 3, NE, being alone triggered

TABLE 1 | Occurrence of concepts related to positive emotions corresponding to one of the four categories.

Groups (sample size)	Concepts (24)	Male (12)	Female (12)	Individuals (12)	Team sports (12)	AG1 18–34y (8)	AG2 35–59y (8)	AG3 +60y (8)
Perceived competence	22	11	11	11	11	8	7	7
Perceived social interaction	19	9	10	9	10	7	6	6
Novelty experience	18	8	10	9	9	5	6	7
Perceived physical exertion	14	10	4	6	8	7	5	2

positive emotions due to cognitive rest or relaxation). The PSI category comprises of all sorts of peer-related aspects like communication with others, to be part of a group and to create close and warm relationships with others such as companionship or friendship. Meeting friends and teammates, spending time together or exercising together, communicating, and socializing made participants experience positive emotions. In other words, accompanied participants described themselves and especially their emotional state more positively and enthusiastically than in situations where they exercised alone without friends or peers:

> *"Because it is so incredibly fun and (despite finding that every now and then I think about quitting) I realize that it is so much fun and such a pleasurable experience and I experience amazing things with my teammates and that's the thing that keeps me going–not so much the success. It is the community, great experiences, and good feelings." "Swimming was enjoyable, but if you are part of a team, it is a lot more fun" "Climbing in a group is like basketball–I really look forward to these amazing days, its similar to snowboarding with several friends a few days–I really enjoy that" "The fun and pleasure is enormous and we all stayed together because we functioned very well as a group" "What one wants to have regularly is to meet the people who are also there and with whom you have fun with and love to train with and everything that goes with it."*

Perceived social interaction as a facilitator of enjoyment and pleasure has reasonable homogeneity among the cells sex, age, or sport-type. Almost the same frequency was found in both sport-types (individual or team): 9 out of 12 individuals compared to 10 out of 12 team sports interviews mentioned PSI related concepts. However, one difference must be considered: the dissimilar description pattern of PSI from the different types of recreational sport. Both, individual and team-sport groups described PSI in a sports-related environment, e.g., meeting people before or after exercise as well as for other non-sporting purposes:

> "*The aim is to have fun with the other girls, and they organize a lot of things to do outside of handball. For them, it is like a replacement for family." "Well I have to say that the camaraderie and the team spirit is quite strong. You travel together to tournaments or drink a beer or go to eat together after training. Some of them also came to my birthday. We also sometimes met at our trainers place to watch a game on his television. That's pretty cool."*

However, participants from team sports also described PSI during exercise or at least directly related to it:

> *"A smile on your face and cheering on your teammates, having fun together and a good time"; "It's really the team spirit which entices me, this kind of sport is fascinating to me."*

On account of this, PSI triggers positive emotions directly through the involvement with others such as teammates or indirectly through the company of others. However, it was the environmental concepts that were the most commonly described. In five interviews participants did not mention any concepts concerning PSI as a facilitator for enjoyment and pleasure in sport and exercise. However, the majority of the participants described positive emotions in situations, when they were in the company of significant others. None of the participants stated negative emotions whilst they were exercising with others (the only exception was at the start of a marathon among hundreds of other people which hindered the performance). The difference between male and female participants was very weak (male 9 out of 12 and female 10 out of 12 participants); this also applied to the three age groups (AG1: seven out of eight, AG2 and AG3: six out of eight). Only two elderly participants explicitly mentioned being fine to exercise on their own, but didn't exclude company *per se*.

> "*Well I also like to go (exercise) alone and enjoy the time I have for myself."*

This is a reference to the third category that describes relief and relaxation when people are able to 'switch off their heads' and let their thoughts go.

Novelty Experience

Thirdly, NE in contrast to the daily life routine was another factor influencing some of the emotional experiences in recreational sport and exercise mentioned in 18 out of 24 interviews. Whilst typically most kinds of exercise are dissimilar to most work-, family-, or other none-sporting commitments and activities, the divergent character of NE lies in the nature of sport and exercise itself. The difference is not limited to activities *per se* and can be found in many dimensions, e.g., the diversity of surroundings, the character of certain people involved in sports or the alternating demand of exercise–sometimes playful or challenging. Concepts such as enjoying the landscape and countryside, to be outside and do outdoor activities- in contrast to most indoor activities, to relax on a cognitive level, to gain new experiences, or to do something non-productive just for fun; curiosity or variety were all grouped into NE.

> *"And when it was lightly raining and you were completely alone out on the water and you are paddling slowly and there is hardly any noise... you really hear the rain on the water, like singing. It's wonderful–at least that's what I think." "On the one hand I find the snow and the mountains amazing, as well as the landscape which is thrilling and the sun–which is enormous," "the otherness of the game compared to daily life, most emotions are triggered by that." "It is when you are on high up in the mountains on a slope and you get this feeling of free movement whilst descending, the swinging to the left and right, and then moving to adapt to the course of the landscape. It is then I get the feeling of pleasure and satisfaction."*

Another part of NE is the cognitive relaxation component. To switch off the brain and let thoughts go, triggers positive emotions in and concentrates the mind on something other than stress and is a contrast to the focus on daily life. Amongst the interviews exercise was often mentioned as an important tool to compensate other influences. NE is only one element of this method, representing the cognitive aspect and must be distinguished from PPE (fourth category), which is related to a physical dimension:

> [When exercising] *"Then I'm not able to think about my job anymore. When I was on the water at the weekend and returned to study on Monday, my head was totally free. I only realized that much later. The mental concentration required while you are sailing- you have to focus on the route, the rules, the environment, and adapting to the elements–had a tremendous recuperative effect on me and I was filled with inner satisfaction and peace." "That moment of diving into the water I find really off-putting but afterward it is pure relaxation. Nothing to think about, nothing else to do. Because of that, I often miscount. Only when I leave the water and have to dry myself, does it turn back to being bad"; "it's more like turning off from your job. That's my goal, switching off from the office job and daily routine and to have a bit of fun doing something you want to do." "You can turn off your head on the track and run because you don't have to do anything in particular and you can simply let your thoughts go."*

In comparison to the male participants (8 out of 12), female participants referred slightly more to concepts related to NE (10 out of 12). However, there were no differences between the individuals and team-sport groups (individuals- 9 out of 12; team sport- 9 out of 12). Among the three age groups a slight increase in the amount of statements about the concepts was found (AG1: five out of eight; AG2: six out of eight; AG3: seven out of eight).

Perceived Physical Exertion

The last factor found was PPE. Concepts related to this category were found in 14 out of 24 interviews. In addition to its psychological component, this category exclusively contains a physical dimension of the body, while the other three are on a pure psychological level. PPE is the phenomenon that sport and exercise *per se* but also fatigue and exhaustion caused by such activities generates a specific and desired emotional response. This effect was described whilst exercising and especially when pushing oneself to the limit but was mentioned more after exercising.

Similarly to NE, this category is also a contrast to the daily life routine with its typical lack of movement and physical demand. Therefore PPE represents an inner drive for movement, the pleasure after exercise or the physical balance desired after long periods of sitting or leading sedentary lifestyle *per se*. Participants referred to positive emotions like pleasure and enjoyment in situations where they could satisfy this drive for movement or do other things that were different to the daily routine such as sport. Even the perception of exhaustion due to strenuous exercise, the opportunity to burn off energy or the growing muscle soreness triggered positive emotions:

> *"The feeling of pleasure during sport is when you are exercising and push yourself, you get feelings of happiness. For me, when I know that I can work out and when I am finished, I pushed myself and afterward I am actually more satisfied and happy." "Well running sometimes feels a bit like torture but nevertheless I feel happy during the run and afterward too." "And if something went wrong you are able to really push yourself to the limit when doing sport and mostly you always feel better afterward. Because of that it is a really good way to balance out my job."*

Another component of PPE is the inner need for movement. People described an impulse to exercise but not necessarily for a certain purpose or a specific goal. They responded with positive emotions whilst fulfilling the desire to exercise:

> *"It has an enormous impact and if I'm not exercising one day I notice that I don't feel as well as I normally do. I need that very much at least once a day, if not more often." "When I arrive at home I feel well balanced, if I wouldn't exercise I would sit at home with the same incomplete work and be frustrated and nervous and in a bad mood. I would then start to concentrate more on the smaller things that aren't so important." "Well the regularity is very important for me, I'm angry if my training is canceled and then I realize that I miss it because I'm not balanced." "I'm used to it. If I was completely without exercise ...well there are some periods in between where you are forced to interrupt exercise but then I miss it quite a lot."*

To underline this point a common theme about missing exercise was very strong among the interviewees. All participants mentioned, that they would miss their familiar sports (24 out of 24).

One crucial part of PPE is the follow-up or rebound effect. In these interviews all participants stated positive emotions after exercising (but only if those emotions were related to a physical response or effect such as exhaustion and not due to evaluation, for example due to a lost match):

> *"When I'm not exercising, I recognize after a while that I'm not feeling physically well. I certainly need to push myself physically and afterward the endorphins are released. You always feel better after having exercised." "I am simply more relaxed and less tense when I'm physically exhausted and you have a total different feeling about life. You sleep very well because you have pushed yourself*

physically and because it cleared your head from thinking about your job you have a better feeling about life. " "Well emotionally balanced and after exercise a happy exhaustion. Therefore, satisfied, happy, and physically exhausted." "It is like a happy exhaustion after a training session. Frequently, I recognized then that I am finished with the training session due to these feelings. It's a kind of very physical happiness." "When you are finished you think about what you have done and that you managed to overcome your doubts and do it, which is probably like a reward system in itself. Well after exercising you have, 99% of the time, positive feelings afterward."

There was a strong difference between male and female participants. 10 out of 12 men reported situations or concepts related to PPE while only 4 out of 12 women did. The need to move, push oneself to their limits, be physically exhausted, or to get the positive emotions afterward was substantially stronger among male participants. The factor sport type, only slightly differed. Individual-participants mentioned 6 out of 12 times concepts related to PPE whilst in 8 out of 12 interviews team participants mentioned it. According to the age factor a strong decline occurred from AG1 (seven out of eight) via AG2 (five out of eight) to AG3 (two out of eight).

DISCUSSION

To change sport and exercise experiences and thus behavior, it is crucial to identify the major influential factors. As described above there is no doubt that positive emotions are major reasons to adopt and maintain corresponding activities (Jekauc, 2015; Rhodes and Kates, 2015; Stenseng et al., 2015), while a lack of positive emotions leads to dropping out (Scanlan and Simons, 1992). Furthermore perceived enjoyment is a key factor for commitment to sport (Scanlan and Lewthwaite, 1986; Scanlan et al., 1993) and reflects a positive emotional response like general feelings (e.g., pleasure) to the sporting experience (Scanlan and Simons, 1992). This study also provides strong evidence for the assumption, that positive emotions such as fun and enjoyment encourage maintenance of recreational sport and exercise in the long term. Participants even referred to positive emotions in a sporting context occasionally without being directly asked (aside from the specific questions). To enhance participation in recreational sport and exercise, commitment and adherence, a better understanding of factors which makes this experience more enjoyable is crucial, starting with the general to the specific (Scanlan and Simons, 1992; Ekkekakis and Petruzzello, 1999).

According to Weiss and Raedeke (2004) the factors *PC, enjoyment*, and the *social environment* impact adherence and maintenance of physical activity among young people. Similarities were described by Scanlan and Simons (1992) with *PC and challenge, social interactions, elements of activity itself,* and *extrinsic rewards* as mediators which often arise in research. In this article, categories similar to the factors *competence, elements of activity and social environment* and, respectively, *social interactions* were found. *Challenge* is included in the first category: PC. Concepts concerning *extrinsic rewards* were not found during the interviews. Similarly to the factors mentioned above, the four categories found in these interviews with an impact on emotional experience are *PC*, *PSI*, *NE,* and *PPE*. Concepts referring to these facilitators occurred frequently among all twenty four interviews suggesting also a dynamic interplay.

Perceived Competence

Perceived competence is one category which is deeply anchored in the character of sport and exercise not only because of the Olympic motto, "Citius–Altius–Fortius" but because in despite of progression, many appropriate activities require special skills to perform them. Positive emotions like fun enhance habits or channel positive behavior change (Rhodes and Kates, 2015; Kwasnicka et al., 2016) while negative emotions strengthen actions to avoid something. PC therefore is a facilitator to evolve toward a certain skill level (Deci and Ryan, 2000; Ekkekakis et al., 2005; Cohn and Fredrickson, 2006) as well as helping to sustain this ability as a result of the fun and enjoyment experienced during sport and exercise. The importance of PC as a facilitator for positive emotions is underlined due to it commonness and robustness among all interviews regardless of the independent factors. Furthermore it might reinforce itself since the perception of competence result in positive emotions which in turn support optimal performance (if perceived as convenient; McCarthy, 2011).

White (1959) was the first, who described the interaction between competence and enjoyment. He proposed an intrinsic drive of an individual to deal effectively with the surrounding environment and the positive emotions after doing so (Harter, 1978). In his opinion *effectance motivation* just aims for the feeling of efficacy, not for any consequences (White, 1959). As described in his basic model, this type of motivation leads to mastery attempts in a certain domain. After a successful attempt and PC, a feeling of efficacy arises, accompanied by pleasure, which in turn increases or at least maintains *effectance motivation* (White, 1959; Harter, 1978).

Based on White's (1959) concept of *effectance motivation*, Harter (1978) developed the competence motivation theory which describes the intrinsic striving of a child to develop competence in certain domains and to achieve mastery level. Related to the amount of competence motivation the child will search for correspondence between challenge and expected success. If the person succeeds in those mastery attempts with an optimal amount of challenge, they will experience PC and control as well as a positive affect response. Significant others may also enhance these perceptions giving social support in different ways and indirectly influence the emotional response. In sum these processes increase the desire "*to continue being effective*" (Weiss and Raedeke, 2004; S.227). It is reasonable to assume that this process applies for the most part equally in older individuals–with its usual characteristic structure but with different intensities of influential behavior and habits.

In summary, in a recreational sport or exercise -related environment, PC is undoubtedly a major facilitator on emotions with a robust effect on the emotional response and furthermore essential for any type of motivation (Deci and Ryan, 2000). Connections to PSI, NE and PPE were found (e.g., collective success, flow, and push to the limit).

Perceived Social Interaction

Humans do have a natural need to establish and sustain close and warm relationships (Maslow, 1968). Forming these bonds as well as amplifying them is ensued by positive emotions such as pleasure and happiness. To trigger these emotions people need frequent social interactions with others, ideally experienced as pleasant and enjoyable. However, more importantly is the perception of belonging and the social tie itself rather than mere social contact (Baumeister and Leary, 1995). Furthermore, a consistent and long-term interaction with familiar people is experienced as more satisfactory than changing partners or strangers. This effect increases due to mutuality, which is supportive but not necessarily essential (Clark, 1984; Baumeister and Leary, 1995). The facilitator PSI may promote positive emotions during sport and exercise and afterward. Most kind of sports provide an appropriate environment for social interactions because many people tend to exercise with others. According to Coon (1946), affiliating in groups is inherently instinctive rather than practical (e.g., cost-effective, same time, interests, etc.). In addition, it seems that behavior change from individuals within a group is more promising than changing them alone (Lewin, 1951; Kwasnicka et al., 2016). Perhaps positive motivation from others who enjoy the physical activity might enhance the attitude toward it and the effect is cumulative. Although this collective reinforcement might also apply to negative emotions, it is reasonable, that the majority of emotions whilst exercising are positive. As the participants stated, –'otherwise people won't continue with an unpleasant activity.' However, PSI as mentioned by the majority of the participants enhances their emotional experience in the context of sport and exercise. This indicates that the need for attachment and belonging is affected which can be considered to be fundamental (Baumeister and Leary, 1995; Lavigne et al., 2011). People experience pleasure and enjoyment when creating new relationships such as entering a new sport, team, or club, but this was even more so when reinforcing or sustaining existing ties (Baumeister and Leary, 1995). On the other hand, it seems that positive emotions also influence belongingness (Stenseng et al., 2015) and due to their reciprocal relationship are self-energizing. Many participants reported, that either their parents or their friends were the initial cause of starting their engagement in sports and exercise–both figures in which the participants have a bond and attachment. PSI might convert recreational sport and exercise into something more attractive. Participants also underlined positive emotions while exercising together with friends or being accompanied by them in an exercise context. These emotions might arise due to the exercise itself, due to the satisfaction of the need to belong or due to a combination of both. Although participants thought that their sporting-activities were enjoyable, they explained that the intensity of positive emotions was weaker when exercising alone. Similarly lower levels of enjoyment were reported from participants who spent time together without recreational sport and exercise. The highest degree of positive emotions occurred when exercising along with others or directly together. Recent findings suggest, that a basic function of emotion is to encourage the formation and sustenance of relationships (Baumeister and Leary, 1995). Because people are happy and also resist the dissolution of relationships, they participate more often and are more likely to continue with recreational sport and exercise much longer than they normally would without these social ties. Along with recent evidence this study confirms the connection between belongingness and positive emotions in recreational sport and exercise (Stenseng et al., 2015). Furthermore relationships with NE and PPE were found (interaction with teammates, reduced negativity of high intensity).

Novelty Experience

According to the Latin proverb, 'variatio delectat,' variation can be seen as a source of positive emotions. Furthermore, the distraction hypothesis may provide an explanation for the 'feel better' effect normally associated with exercise. It assumes, that distraction from stressful stimuli rather than the physical exercise itself enhances positive emotions (Morgan, 1985). Participants often reported, that they enjoyed situations in which they could 'turn off their head' and let their thoughts go. However, research could not verify a stronger impact of exercise in terms of distraction in comparison to equivalent activities such as rest or relaxation on emotional states (Yeung, 1996). It seems that the distraction hypothesis is not able to explain why participants choose exercise rather than rest or relaxation. Other distractions and influences due to cognitive factors such as non-associative thoughts about external surroundings, etc. might affect mood states during exercise (Goode and Roth, 1993), however, the intensity of this cognitive task must still match (Fillingim et al., 1989). Yeung (1996), concludes that the effect of exercise on negative emotions is not superior compared to equivalent activities for distraction but in fact is superior when it comes to improving positive mood. If the attitude toward exercise is positive, distraction might reinforce that. Cognitive processes might attenuate negative signals from the body and as a result the overall sensation is primarily positive (this mechanism is discussed further in category 4, PPE).

Another approach might be the theory of sensation seeking, a concept which describes the need for various, novel and complex sensations and the acceptance of accompanied risks (Zuckerman, 1979). Although the four scales (*thrill and adventure seeking, experience seeking, disinhibition, and boredom susceptibility*) suit NE on first impression, the differences found among the three independent factors did not match with recent evidence. While sensation seeking is stronger amongst younger people and men (Zuckerman et al., 1978; Steinberg et al., 2008; Cross et al., 2013), the participants reported the opposite in terms of age, sex, and readiness to assume risk.

Since sensory deprivation reinforces inter alia the urge to move and extrinsic sensory stimuli (Solomon et al., 1957), people might desire similar needs without such need for extremes.

The seeming paradox of this category is that new experiences and impressions, curiosity and excitement are completely opposite to relaxation and cognitive balance or rest which are also comprised in NE. However, both dimensions share in common a positive valence and the contrast to the daily life routine even though they are opposites. The first form of NE describes the positive state of 'feelings' in such a situation-high arousal and activation of a person. Seeking sensation, adventure, challenge, or just the desire not only to move but also to gain other experiences in comparison to everyday life might be one explanation for such an emotional response and resulting behavior. The second appearance of NE describes the lower but fair arousal and activation of a person seeking some relaxation and rest. In this particular situation people also described positive emotions in contrast to a stressful daily routine, which meant switching off and letting their thoughts go. In both forms of NE the outcome is nearly the same: positive emotions, enjoyment, and satisfaction. However, the trigger is a different one. Therefore none of the participants described a relaxation effect following a state of excitement or curiosity accompanied by rest.

Positive emotions were intended to promote curiosity and novelty to explore the surroundings for resources (Ekkekakis et al., 2005; Cohn and Fredrickson, 2006) rather than responding to a stimulus demonstrating a strong affinity between NE and positive emotions. Phenomena such as the 'runners high' underline the interplay between NE and PPE.

Perceived Physical Exertion

In relation to exercise-intensity, the emotional response of individuals differs in terms of magnitude, direction, or accountable sources (Ekkekakis and Petruzzello, 1999; Ekkekakis et al., 2000, 2005; van Landuyt et al., 2000; Hall et al., 2002; Ekkekakis, 2003). It is reasonable to assume, that individuals always seek the best emotional outcome and choose the appropriate intensity accordingly, whereas a deviation might lead to less pleasure and enjoyment (Ekkekakis, 2003; Ekkekakis et al., 2005; Ekkekakis and Lind, 2006; Vazou-Ekkekakis and Ekkekakis, 2009). However, some people experience positive emotions at lower levels of intensity and duration of exercise (Ekkekakis and Petruzzello, 1999; Ekkekakis et al., 2000; Reed and Ones, 2006), while some feel comfortable with moderate to high exercise intensity, others will not (Yeung, 1996; van Landuyt et al., 2000; Ekkekakis, 2003). As intensity approaches functional limits, divergent sensations vanished as well as positive valence (Ekkekakis and Petruzzello, 1999; Hall et al., 2002; Ekkekakis, 2003, 2009; Ekkekakis et al., 2005, 2011). Despite these negative emotions some participants (especially those with a higher fitness level) chose demanding intensities and pushed themselves to their limits possibly to generate a higher physical contrast to that of the daily life demand on the body via exhaustion or pain ["hurt so good"(Ekkekakis, 2003)]. Perhaps other influences attenuate the unpleasant sensations associated with strenuous exercise and generate the desire to exercise. Although the main impact on emotions in this domain is physical and increases proportionally with exercise intensity whilst cognitive effects diminish (Ekkekakis, 2003, 2009). However, it still has a cognitive component (e.g., conscience, pride, guilt, etc.; connection to the first category PC).

Another explanation, why people choose intensities that have minimal positive emotions might be due to a *follow-up* or *rebound effect* after the physical activity is finished. In general, exercise is consistently ensued by positive emotions (Tuson and Sinyor, 1993; Yeung, 1996; Ekkekakis, 2003), even if it is at a demanding intensity (Hall et al., 2002). This is despite recent emotional bias during exercise (Ekkekakis and Petruzzello, 1999) which might exceed pre-exercise states independently of intensity (Ekkekakis et al., 2008). This *affective contrast* (Solomon, 1980, 1991) might be due to an interference of two affective dynamic processes with different patterns in terms of effect direction, emergence, and duration. In contrast to each other, the a-process has a negative valence, which is stimulated beyond a certain threshold, then matches the intensity and disappears along with it. Whereas the b-process has a positive valence, is triggered by the first, has a completely opposite bias and appears to be more consistent with slower emergence and decline (Solomon, 1980, 1991). The sensation during exercise is the result of subtraction of both whereas in the recovery-phase the b-process solely determines the emotional outcome. This leads to the conclusion that during high intensity exercise individuals might experience negative emotions, due to a high salient influence of the a-process, but afterward the emotional response is always positive because only the b-process remains. The concept of flow (Csikszentmihalyi, 1975) or phenomena such as the 'runners high' might be reflected through the b-process during exercise and mark the threshold where positive emotions occur. However, the a-process might include interoceptive signals which rise as the intensity increases whereas the b-process is charged with cognitive signals which diminish with growing intensity in favor of the first process, which is similar to the dual mode concept (Ekkekakis, 2003, 2009). Another explanation for positive emotions due to the influence of the b-process might be a feeling of relief and alleviation accompanied by biochemical processes inducing regeneration (Hatfield and Landers, 1986). Due to this relationship, positive emotions vanish whilst exercise intensity increases and will return immediately upon exercise cessation explaining the 'feel-better-effect' commonly mentioned by participants and people in general (Morgan, 1985). In other words, some individuals may not initially enjoy the activity itself but seek the positive emotions afterward. Statements among those interviewed supported these notions. However, in their review, Rhodes and Kates (2015) did not find any evidence, that post-exercise emotional experience influenced future exercise behavior. Either a lack of sensitivity and power of the method, different mechanics between emotional experience during and after exercise, aforementioned relationships with other facilitators or habitual issues such as the overall exercise experience which might attenuate current emotional influences cause this contrariness which must be clarified through future research.

Relating to the strong difference in terms of sex, references to a higher intensity and especially to exceeding physical limits and pushing oneself hard were noticeably common amongst men. According to the opponent-process model (Solomon, 1980, 1991), men might have a higher resistance to the a-process or potent factors like PC (category 1) boosting the b-process, whilst women do not. Reinforced by a weaker fitness level, they perceive exercise as more strenuous and less pleasant and may avoid higher intensity exercise (Ekkekakis and Petruzzello, 1999; Ekkekakis and Lind, 2006).

The difference in terms of sport type is small. While participants in individual recreational sports could decide autonomously, those people in a team or group must adapt to the collective intensity expected–this normally results in a decrease of positive valence (Dishman et al., 1994; Ekkekakis and Petruzzello, 1999; Vazou-Ekkekakis and Ekkekakis, 2009) as well as it being due to supra-threshold intensities (Ekkekakis et al., 2011). However, the slightly higher frequency in positive emotion-related statements of team-sports participants suggests that team-dynamics as well as providing a distraction attenuate the interoceptive signals that improve the resistance to the a-process, raise the threshold and reinforce the b-process during exercise and later on as well.

The age groups show a strong decline in positive emotions related to exercise intensity. A transition from interoceptive dominance at a younger age to cognitive dominance can be expected. According to the opponent-process model (R. L. Solomon, 1980, 1991), a higher resistance to the a-process or a higher sensitivity to the b-process and lower self-awareness at a younger age might reflect the urge to move and the need for vigorous exercise. An inverted relationship at an older age with higher maturity induces avoidance to strenuous exercise not only because of health issues, restrictions, and ailments but actually increased rationalizing results in the motivation to do exercise for other reasons. As one ages the threshold for desired high intensity exercise seems to weaken which is reinforced by a decreasing fitness level influencing the overall exercise experience (Ekkekakis et al., 2005).

Self Determination Theory

According to the self determination theory (Deci and Ryan, 2010) humans have three psychological needs which are essential for intrinsic motivation to adopt and adhere behavior (Kwasnicka et al., 2016) or an activity in particular: the need for competence, relatedness, and autonomy. Although the theory is focused on intrinsic and extrinsic motivation and this study is focused on facilitators of positive emotions, the similarities are striking. The perception of competence and affiliation plays an important role to elicit positive emotions through satisfaction of these basic needs. This leads to the assumption, that positive emotions and intrinsic motivation are related constructs. Furthermore it is not surprising that the need for autonomy was not as strong as the other two among the interviews since all participants were voluntary involved in recreational sports in their leisure time and autonomy was naturally present. Nevertheless there are some characteristics of autonomy in common with NE, such as self-control or the ability to choose, e.g., skiing or sailing a self-chosen course or running at one's own desired pace. Additionally NE is described as contrast to the repetition of daily routine which contains commitments and limited autonomy. However, when this is restricted due to a forced interruption (e.g., such as injuries or appointments) this negate any positive emotions. The selective coding process revealed that even a high level of perception of competence or relatedness seemed to both facilitate positive emotions even more if this perception was further increased, e.g., one is performing well and later on is victorious or teammates become close friends. In contrast references to autonomy were more common when it was threatened which indicates, that in this case it is a much stronger facilitator for negative emotions. However, as an avenue for future work the different function of negative emotions (e.g., survival, avoid harm) and positive emotions (e.g., adaptation, extend resources) require separate attention since negative emotions influence behavior in a different way (Cohn and Fredrickson, 2006).

Implications

This study is a novel and perhaps promising approach to illuminate facilitators of positive emotions to explain exercise maintenance. Firstly, these findings encourage continuation of practical application studies to advance the knowledge about potential facilitators of emotional responses to exercise. Secondly, based on these results, interventions could be developed which enhance the emotional response during exercise by manipulating these four facilitators (e.g., due to a corresponding design or instructor behavior). Thirdly, recommendations for the design and evaluation of exercise programs can be made in so far as to reduce the drop-out rate and to increase commitment and adherence to sport. In an experimental study, Jekauc (2015) could show that emotions could be manipulated to increase adherence in exercise. However, further quantitative studies are needed to explicitly test the relevance of the factors discovered here.

Strength and Limitations

This study has some strengths and limitations. For the best approach to the emotional dimension, Dishman (1994) and Rhodes et al. (2009) proposed a qualitative and therefore inductive design because qualitative methods meant having a higher capability to illuminate the different sources of enjoyment by including a broad spectrum of influences as expected in the sporting environment (Scanlan and Simons, 1992). Also the value of information is much higher if participants are able to express their feelings with their own words. They might reveal factors which might otherwise be missed. The semi structure interview guide guaranteed a uniform approach. For a qualitative study, it has quite a large sample of 24 participants which is heterogeneous as sex, age, and type of sport are systematically varied. Furthermore the analysis via Grounded Theory ensured systematical categorization.

However, the sample is not large enough to be a representative sample. Despite a progressive but sometimes deficient differentiation of constructs and convergence of several theories, terms in the literature are still used inconsistently which hinders the ability to compare. Presented findings were drawn from recreational sport and exercise and might not count for specific aspects such as competitive sport or for a broader remit such as physical activity.

CONCLUSION

In this study, four facilitators of positive emotions during exercise and recreational sport were identified: *PC*, *PSI*, *NE*, and *PPE*. These results could provide the starting point for the development of interventions aiming at the promotion of positive emotional states in sport in order to increase maintenance and adherence to sport and exercise. Future steps will be to design intervention studies according to the findings of this study and to test their effectiveness in experimental studies.

AUTHOR CONTRIBUTIONS

BW is the main author of the submitted article and responsible for the overall conception and design of this manuscript. He is also responsible for the data collection, analysis, and interpretation. DJ is the second author and contributed to the design of the study, he was involved in the interpretation and provided edits to the paper. Both authors read and approved the final manuscript.

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Exercise Experiences and Changes in Affective Attitude: Direct and Indirect Effects of *In Situ* Measurements of Experiences

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Objectives: The purpose of this study was to examine the relationship between exercise experiences (perceptions of competence, perceived exertion, acute affective responses to exercise) and affective attitudes toward exercise. This relationship was analyzed in a non-laboratory setting during a 13-weeks exercise program.

Materials and Methods: 56 women and 49 men (aged 35–65 years; M_{age} = 50.0 years; SD = 8.2 years) took part in the longitudinal study. Affective responses to exercise (affective valence, positive activation, calmness) as well as perceptions of competence and perceived exertion were measured at the beginning, during, and end of three exercise sessions within the 13-weeks exercise program. Affective attitude toward exercise were measured before and at the end of the exercise program. A two-level path analysis was conducted. The direct and indirect effects of exercise experiences on changes in affective attitude were analyzed on the between-person level: firstly, it was tested whether perceptions of competence and perceived exertion directly relate to changes in affective attitude. Secondly, it was assessed whether perceptions of competence and perceived exertion indirectly relate to changes in affective attitudes—imparted via the affective response during exercise.

Results and Conclusion: At the between-person level, a direct effect on changes in affective attitude was found for perceptions of competence ($\beta = 0.24$, $p < 0.05$). The model revealed one significant indirect pathway between perceived exertion and changes in affective attitude via positive activation: on average, the less strenuous people perceive physical exercise to be, the more awake they will feel during exercise ($\beta = -0.57$, $p < 0.05$). Those people with higher average levels of positive activation during exercise exhibit more improvements in affective attitudes toward exercise from the beginning to the end of the 13-weeks exercise program ($\beta = 0.24$, $p < 0.05$).

Main study results have revealed that *in situ* experiences predicted changes in affective attitude during multi-week exercise programs. These relevant *in situ* experiences encompass cognitive factors, the sensation of interoceptive cues, and affective responses to exercise. Considering the predictive role of affective attitudes for exercise behavior, these findings suggest that exercise interventions should put greater emphasis on specific exercise experiences.

Keywords: physical exercise, affective response, perceptions of competence, perceived exertion, affective attitudes toward exercise

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INTRODUCTION

The positive effect of physical exercise on health has already been demonstrated (Physical Activity Guidelines Advisory Committee Report, 2008). Nevertheless, surveys among the general population show that the majority of adults in Western industrialized countries do not exercise enough (European Commission, 2014). Encouraging participation in exercise is therefore an important assignment for society and policy-makers.

In order to create effective interventions, it is crucial to identify factors and mechanisms associated with the initiation and maintenance of physical exercise behavior (e.g., Michie and Abraham, 2004; Biddle and Fuchs, 2009). Several psychological theories have been developed that feature prominently in explaining health behavior [e.g., social cognitive theory (Bandura, 1997); theory of planned behavior (Ajzen, 1988); health action process approach (Schwarzer, 2008)]. In recent years, these theories have been advanced in the domain of physical exercise.

Particularly, research has placed a stronger focus on the role of affective processes in initiating and maintaining regular physical exercise. For example, existing studies based on the theory of planned behavior have for the most part predicted exercise behavior via instrumental attitudes (e.g., cognitive convictions about the benefits of physical exercise, Lawton et al., 2009). More recent work, however, has shown that affective attitudes toward exercise (i.e., whether thinking about doing physical exercise makes one feel comfortable or uncomfortable) is at least as successful at explaining exercise behavior (e.g., Lowe et al., 2002; Brand, 2006; Kiviniemi et al., 2007). Further evidence for the particular relevance of affective associations to exercise could be drawn from recent studies that differentiate between distal and proximal outcome expectancies. Outcome expectancies are closely related to affective attitudes toward exercise when they are proximal to the behavior itself and refer to affective states (e.g., "When I exercise, then I will feel better"). These proximal outcome expectancies predict exercise intention and behavior to a greater degree than distal outcome expectancies like future health benefits (Gellert et al., 2012). Furthermore, the fulfillment of proximal outcome expectancies (e.g., in terms of emotional reward) provides a crucial mechanism for long-term exercise change as it supports volitional effort in goal-directed behavior (Klusmann et al., 2016).

Moreover, recent research indicates that exercise experiences need to be better integrated with advancements in exercise behavior theories. Psychological and physical experiences appear to be especially relevant for the longer-term maintenance of exercise behavior (Rothman, 2000). There is some initial empirical support that positive exercise experiences influence subsequent affective outcome expectancies (Loehr et al., 2014) or satisfaction with the exercise behavior (Fleig et al., 2011; Baldwin et al., 2013).

One of the few models that integrate both exercise experiences and (affective) attitudes is the transdisciplinary framework model put forward by Bryan et al. (2011). They assume that exercise experiences, such as perceived exertion or changes in affect, influence attitudes, which in turn predict exercise behavior. However, the model is heuristic in nature. Experiences, for instance, are aggregated into a single category, and possible relationships between different experiences are not put into concrete terms. Furthermore, it is unclear *which* exercise experiences alter affective attitudes. This represents the starting point for this paper, which aims to investigate the mechanisms operating between exercise experiences and changes in affective attitude.

Changes in Affective Attitude: Potential Mechanisms

Existing intervention studies on changes in affective attitude toward physical exercise support the assumption that affective attitudes are influenced by one's personal experiences with exercise (Rhodes et al., 2009). Thus, Williams (2008) assumed that specific exercise experiences influence affective responses to physical exercise, and these in turn alter affective attitudes and favor longer-term exercise adherence (see **Figure 1**, indirect effect). On the one hand, Williams (2008) draws on dual mode theory (e.g., Ekkekakis and Acevedo, 2006), which explains different affective responses to exercise activities, firstly in terms of cognitive aspects. One cognitive factor often examined in this context are perceptions of competence (e.g., Rose and Parfitt, 2007). Positive perceptions of competence arise when a (motoric) task can be performed using one's own skills and abilities. A positive connection between this and affective responses has been repeatedly demonstrated (e.g., Rose and Parfitt, 2012). Secondly, dual mode theory explains different affective responses to exercise activities in terms of interoceptive cues. Interoceptive cues, which may be triggered by physical exercise, include such sensations as having difficulty breathing or increased body temperature. A global indicator for experiencing interoceptive cues is perceived exertion. This again is defined as "a configuration of sensations: strain, aches and fatigue involving the muscles and the cardiovascular and pulmonary systems during exercise" (Groslambert and Mahon, 2006, p. 912). There is empirical evidence which confirms that perceived exertion is negatively connected to affective responses to physical exercise (e.g., Williams et al., 2008; Barnett, 2013). On the other hand, Williams also drew on hedonistic theories, which state that human beings are programed by evolution to seek pleasure and avoid pain (Kahnemann, 1999). Experiencing pleasure while exercising forges the corresponding affective associations, which in turn reinforce the repetition of exercise behavior.

Aside from an indirect link between exercise experiences and changes in affective attitude, a direct connection is also feasible. For example, Vlachopoulos and Michailidou (2006) were able to show that perceived competence is linked to affective attitudes (see **Figure 1**, direct effect). This indicates a direct relationship between the cognitive appraisal of one's own abilities and affective attitudes toward exercise. However, we did not find studies on the connection between perceived exertion and changes in affective attitude during exercise activities.

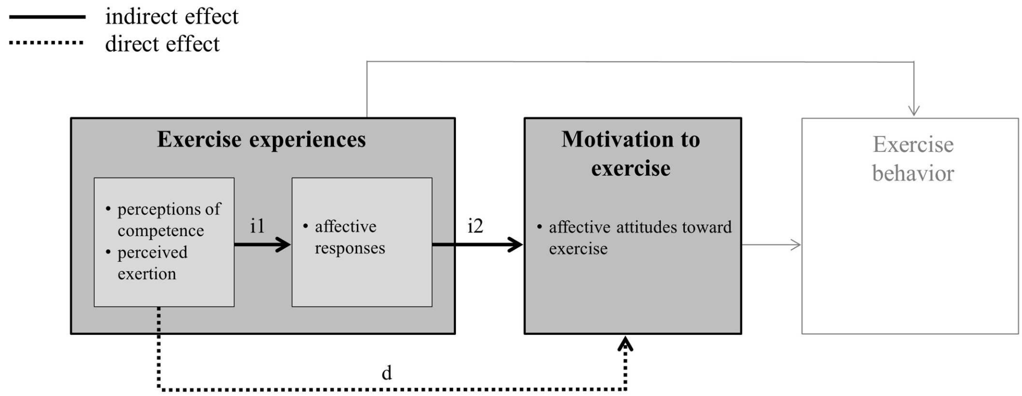

FIGURE 1 | Conceptual model of changes in affective attitude toward exercise (based on Bryan et al., 2011).

Affective Responses to Exercise in the Behavior Change Research

Affective responses to exercise are connected to motivation and exercise behavior (e.g., Kwan and Bryan, 2010; Williams et al., 2012). When studying these relationships, three conceptual and methodological issues need to be considered:

(1) The dimensional approach of basic affect: the conceptualization and measurement of affective responses to exercise are either based on a categorical or a dimensional approach. According to a categorical approach affective states are organized into distinct categories. Researchers often use several distinct categories, such as depression, tension, confusion, anger, fatigue, vigor, or anxiety. According to a dimensional approach affective states are systematically interrelated. Therefore, they can be described using only a few basic affect dimensions. There is some empirical support for the three dimensions affective valence (e.g., discontent – content), positive activation (e.g., tired – awake) and calmness (e.g., tense – relaxed; Schimmack and Grob, 2000). In the present study affective response is examined from a dimensional approach. Since it is unclear, which specific affective state is the most important for physical exercise motivation, a broad perspective is more likely "to capture the essence of exercise-induced affect" (Gauvin and Brawley, 1993, p. 152). An additional advantage of the dimensional approach is that affective states can be measured more efficiently. The measurement of a few basic dimensions using only a few reliable items per dimension is particularly suitable for study designs with frequently repeated measurements (Ekkekakis, 2008).

(2) Time of affect measurement: affective responses vary depending on the time at which affect is measured (Ekkekakis et al., 2011). Affective responses during physical exercise display a greater inter-individual variability than those occurring afterward. If affective states are only determined before and after exercise, there is the danger that one will actually measure the response to finishing the activity, which is usually positive (Hall et al., 2002; Backhouse et al., 2007). Possibly, it is this high inter-individual variability during exercise which is particularly significant for explaining the various motivations for exercising (Kwan and Bryan, 2010).

(3) Intra-individual differences in affective responses to exercise: in the behavior change research, the majority of studies measure affective responses to exercising during a single exercise session (Kwan and Bryan, 2010; Williams et al., 2012). Thus, intra-individual consistency in affective responses is rarely taken into account. A recent study with overweight and obese women demonstrated that pre-to-post-exercise changes in affect within an individual varied across three identical, moderate-intensity treadmill exercise sessions (ICCs = 0.02–0.60, Unick et al., 2015). In contrast, affective responses during exercise were more consistent (ICC = 0.72), especially when controlling for pre-exercise scores (ICC = 0.83).

In sum, current research indicates that it is important to assess affective responses especially *during* exercise. To obtain reliable information about affective responses to exercise, they should be measured more than once. Additionally, existing studies often examined physical exercises in controlled laboratory conditions. Thus, whether affective responses to exercise in a laboratory setting are representative of a participant's real-world affective response remain unclear (Liao et al., 2015).

Aims and Rationale of the Present Study

The aim of the present study is to examine the relationship between exercise experiences and changes in affective attitude (see **Figure 1**). In the category of experiences, perceptions of competence and perceived exertion are examined, as well as affective responses to physical exercise. Following the example of Williams (2008), we assume that the perceptions of competence (positively) and perceived exertion (negatively) impact affective attitudes as partially mediated via affective responses to exercise. This indirect path of operation is compared with a direct path of operation, in which it is evaluated whether perceptions of competence and perceived exertion directly predict changes in affective attitude.

Compared to the current state of the research, the present study stands out due to the following extensions:

(1) Exercise experiences are measured *in situ* during exercising. In previous studies, exercise experiences were measured retrospectively—for example, concerning the period of the last few weeks (Fleig et al., 2011; Parschau et al., 2013). Moreover, in some diary studies exercise experiences were recorded on a weekly basis (Loehr et al., 2014) or on a daily basis (Baldwin et al., 2013). The latter studies revealed that it is especially worthwhile to assess exercise experiences as close as possible to the actual activities in order to gain insights into their specific qualities.
(2) Exercise experiences are measured in a non-laboratory setting. In doing so, variables can be measured closer to usual, naturalistic conditions than it is done in other current studies with controlled laboratory conditions.
(3) The three basic affective dimensions—affective valence, positive activation, and calmness—are simultaneously integrated into our analysis. Thereby, our study helps clarify which affective dimensions have an effect on affective attitudes toward exercise.
(4) As affective responses to exercise within an individual vary across different exercise sessions (Unick et al., 2015), observations of exercise experiences in multiple exercise sessions provide a reliable assessment of exercise experiences in the present study. In order to consider personal characteristics of the participants, we included physical fitness as control variable for affective responses during exercising (Ekkekakis et al., 2011).
(5) Affective attitudes are measured twice, 13 weeks apart, and are modeled as a latent change (LC) variable in the analyses (Reuter et al., 2010). This allows us to adequately model the dynamics of this connection: exercise experiences should be associated with *medium-term change* in affective attitude.

As previously stated, we test the assumptions made by Williams (2008) and, therefore, compare indirect and direct associations between inter-individual differences in exercise experiences and changes in affective attitude. However, repeated measurements of exercise experiences make it possible to consider both inter-individual (between-person) variations and intra-individual (within-person) variations in the features under study. Therefore, we chose a multi-level approach and applied a two-level path analysis. The multi-level approach is of particular relevance for the first part of the indirect effects under study (see **Figure 1**). The links between exercise experiences and affective responses to exercise can have different meanings depending on whether between-person variations or within-person variations are being analyzed (e.g., Hamaker, 2012). Considering, for example, a negative relationship between perceived exertion and affective responses to exercise on the between-person level would mean that persons who experience on average a higher level of perceived exertion when exercising would have less positive affective responses. In contrast, the same negative relationship on the within-person level would mean that a given individual in different exercise sessions would exhibit a more negative affective response if the activity were perceived as being more strenuous. If the decomposition of between-person effects and within-person effects were ignored and only between-person effects were considered, an improper generalization of between-person effects could occur. The between-person relationship would be inappropriately generalized to intra-individual relationships between perceived exertion and affective valence. Against this background, it is important to note that the primary focus of the present study is on inter-individual differences in exercise experiences and changes in affective attitude (between-person effects). However, considering both within-person effects and between-person effects minimize the risk of possible misinterpretations of the results for the first part of the indirect pathway on the between-person level, which is of primary interest for the confirmatory hypotheses of the present study.

Aside from this confirmatory test of the hypotheses, this study also includes explorative parts. For instance, no *a priori* assumptions were made as to *which* of the three affective dimensions is connected to perceptions of competence and perceived exertion. Moreover, no assumptions were made about within-person associations between exercise experiences and affective responses to exercise due to the lack of previous studies that have examined within-person variations of exercise experiences during exercise. Finally, no assumptions were made about *which* of the three affective dimensions, has a direct effect on changes in affective attitude.

MATERIALS AND METHODS

The present study is based on data from the research project "Which sport for whom?" This project was a quasi-experimental intervention study investigating the effectiveness of five newly created exercise programs as regards promoting subjective well-being and exercise behavior.

Participants

The sample consisted of academic and non-academic staff from a university in the German-speaking part of Switzerland. It comprised of 80 women and 53 men. Their average age was 49.5 years ($SD = 8.3$). Most were married (61%), and their highest level of education was a degree from a university or a university of applied science (65%). A survey based on a 7-days recall procedure (Mäder et al., 2006) revealed that, at the beginning of the study, 23% engaged in no exercise at all and 6% exercised for less than 1 h per week; 21% exercised for 1–2 h per week; 23% exercised for 2–4 h per week and 26% for more than 4 h. The objectively measured body mass index showed that 67% had normal body weight, whereas, 24% were overweight and 9% obese (see **Table 1**).

Instruments

Affective Attitudes toward Exercise

To measure affective attitudes toward exercise, we applied a questionnaire by Crites et al. (1994), whose German-language version was validated by Brand (2006). This instrument

TABLE 1 | Sample characteristics.

		Total sample ($n = 133$)		Reduced sample ($n = 105$)	
		n	%	*n*	%
Sex	Male	53	39.8	49	46.7
	Female	80	60.2	56	53.3
Marital status	Married	73	61.3	59	62.8
	Unmarried	27	22.7	20	21.2
	Divorced/separate	19	16.0	15	16.0
	Not available	14	–	11	–
Highest education	Professional honor	19	16.2	13	14.3
	College of professional Education and training	18	14.5	13	13.3
	University or university of applied science	80	64.5	66	67.3
	Other	6	4.8	5	5.1
	Not available	9	–	7	–
Exercise behavior	No exercise	30	23.4	24	23.8
	<1 h/week	8	6.3	7	6.9
	1–2 h/week	27	21.1	21	20.8
	2–4 h/week	30	23.4	23	22.8
	>4 h/week	33	25.8	26	25.7
	Not available	5	–	4	–
Body weight	Normal	73	67.0	57	67.1
	Overweight	26	23.9	22	25.9
	Obese	10	9.1	6	7.0
	Not available	24	–	20	–
Exercise programs	Active and recreated	20	15.2	16	15.4
	Reload and relax	26	19.7	18	17.3
	Together fit	13	9.8	13	12.5
	SPORT Varia	32	24.2	26	25.0
	Body and (e)motion	42	31.1	32	29.8
Age		$M = 49.5$ $SD = 8.3$		$M = 50.0$ $SD = 8.2$	

comprises four items based on the phrase: "When I think about exercising, I feel..." Answers follow a semantic differential of values from 1 to 9. The answers to the four items are: *"not relaxed"* – *"extremely relaxed"* (AFF1); *"not satisfied"* – *"extremely satisfied"* (AFF2); *"not happy"* – *"extremely happy"* (AFF3); *"not uncomfortable"* – *"extremely uncomfortable"* (AFF4). This last item proved to have a comparatively low discriminatory power due to the double negative (pre-test: $r_{it} = 0.50$; post-test: $r_{it} = 0.50$) and was therefore removed from the scale. The internal consistency of the remaining three items was good in the existing sample (pre-test: $\alpha = 0.82$; post-test: $\alpha = 0.92$).

Affective Response to Exercise

Affective states were measured using Wilhelm and Schoebi's (2007) short, German-language scale for assessing the three basic dimensions affective valence, positive activation, and calmness (Schimmack and Grob, 2000). Validating studies have shown that these three bipolar dimensions can be reliably established by means of the corresponding two items (Wilhelm and Schoebi, 2007). Bipolar pairs of adjectives served as indicators to register affective valence (*"discontented"* – *"contented," "unwell"* – *"well"*), calmness (*"tense"* – *"relaxed," "agitated"* – *"calm"*) and positive activation (*"tired"* – *"awake," "full of energy"* – *"without energy"*). For each pair of adjectives, participants had to answer the question "At this moment, I am feeling..." on a seven-point scale ranging from 0 to 6. In our own sample, the inter-item correlations within the three dimensions were satisfactory to good (affective valence: $0.58 \leq r \leq 0.74$; calmness: $0.61 \leq r \leq 0.68$; positive activation: $0.59 \leq r \leq 0.76$).

Perceived Exertion

Ratings of perceived exertion were established with reference to a validated, German-language scale by Buskies and Boeckh-Behrens (2000). This instrument is a simplified version of Borg's (1982) scale for rating perceived exertion. The participants answered the question: "How exerting did you find the activity?" on a seven-point scale, with answers expressed in words [(1) *"very light,"* (2) *"light,"* (3) *"rather light,"* (4) *"moderate,"* (5) *"somewhat hard,"* (6) *"hard,"* (7) *"very hard"*]. Buskies and Boeckh-Behrens recommend this procedure with less experienced exercisers when preparatory exercises for answering a differentiated Borg-scale are not possible.

Perceptions of Competence

We introduced a single item to establish perceptions of competence. This item was phrased with reference to the sub dimension "challenge-skill balance" from the flow state scale (Jackson and Marsh, 1996). The question: "When you think about today's exercise session: what experience have you gained?" was to be answered using the statement: "The feeling of being competent enough to fulfill the demands of the exercise session" on a six-point rating scale (0 "*not at all true*" up to 5 "*completely true*").

Perceived Physical Fitness

The level of physical fitness was measured by subjective ratings. We applied a modified version of the subscale "physical fitness" from the adjective list for assessing the perceived physical state (PEPS; Kleinert, 2006; Schneider et al., 2010). Participants were asked to spontaneously judge to what extent they feel "strong," "fit," and "enduring." They had to answer on a six-point rating scale (0 "*not at all*" up to 5 "*totally*"). The internal consistency for this modified subscale was good ($0.82 \leq \alpha \leq 0.88$; see also Sudeck and Conzelmann, 2014). The mean score of the three items was used in the further analyses.

Procedures

In order to recruit the participants, letters were sent to all university employees by post or by e-mail. They were informed that the university sports department was going to offer its employees between the ages of 35–65 years five different new exercise programs.

In brief, the titles and contents of the exercise programs were:

(a) Active and recreated: a combination of endurance and strength training without equipment; short sequence of active relaxation exercises at the end of a session (5–10 min).
(b) Reload and relax: various fitness activities; separate relaxation period at the end of each session (15–20 min).
(c) Together fit: health-oriented aerobic endurance and strength training combined with little games; sociable, playful setting.
(d) SPORT Varia: a combination of sports games and endurance activities; sociable formats.
(e) Body and (e)motion: dancing and rhythmic activities, music-oriented fitness training.

If an employee was interested, they filled in a written application to attend one of the exercise programs and agreed to participate in the study, after being informed about its goals and procedure in line with the Declaration of Helsinki. The ethics commission of the Faculty of Humanities of the University of Bern evaluated the study design and procedures as ethically unproblematic.

Affective attitudes toward exercise was assessed at the beginning (pre-test at month 1; see **Figure 2**) and at the end of the intervention period (post-test in month 4). To do this, we set up online questionnaires and sent the participants links by e-mail. A personal registration number enabled us to collate an individual's data pseudo-anonymously.

Program sessions were held once a week during a 13-weeks intervention period. Each session lasted 60 min. The first 40–50 min of the sessions were relatively similar in all programs. Physical exercises with a predominantly moderate to strenuous intensity were carried out and the exercises were guided and carried out in groups. For this reason, it is only the affective responses during these first 40–50 min that are of interest for the primary research question.[1] Affective states, perceived exertion, perceptions of competence, and the perceived fitness level were assessed in three out of the 13 exercise sessions. For these three sessions, all trainers were asked to realize typical sessions. Affective states were measured immediately before the exercise session and twice during the session (approximately between minutes 10 and 15, as well as between minutes 40 and 50). The perceived fitness level was assessed before the session. The perceived exertion was assessed twice during each exercise session. Since the regular course sessions ought to be only minimally interrupted out of respect for the course instructors and participants, we dispensed with collecting further survey content during the session. For this reason, perceptions of competence was measured only once at the end of the exercise session. These assessments were carried out using the software IzyBuilder 2.0 on a handheld computer (HP iPAQ114). In all three sessions, a trained student was present. He gave a hand signal to the participants when it was time to fill out the surveys and provided assistance in case of any problems with the handheld computers.

The study was carried out in two waves. Of the 133 subjects in total, 103 took part in one of the five exercise programs for the first time in wave one, and 30 in wave two. In order not to burden participants with immediate data collection, the handheld computer surveys took place at intervals of 2–4 weeks. For organizational reasons, it was not possible to carry out the three handheld computer surveys in wave one and two in the same course weeks (see **Figure 2**).

The following analyses are based on a reduced sample of 105 individuals (see **Table 1**). Twenty-three people were excluded from the calculations because no handheld survey data was available. Five more individuals were excluded as no online survey data was available. Comparing those participants who were included with those who were excluded from the data analyses revealed no relevant differences in terms of age, education level, BMI, past exercise behavior, or baseline scores on affective attitudes toward exercise ($ps > 0.10$). More women than men were excluded from the study ($p < 0.05$).

Data Analyses

Preparatory Data Reduction

As described in Section "Procedures," two measurements for the affective responses during an exercise session were applied. The

[1] It is important to note that the different types of exercises in the exercise programs are not a consideration in this work. With regard to the affective responses, we focused on physical exercises taking place in a natural, non-laboratory testing environment. Affective responses to techniques of relaxation are not taken into consideration. As such techniques of relaxation were systematically carried out at the end of the sessions in two out of the five programs, the affective states at the end of the sessions were not included in the analyses.

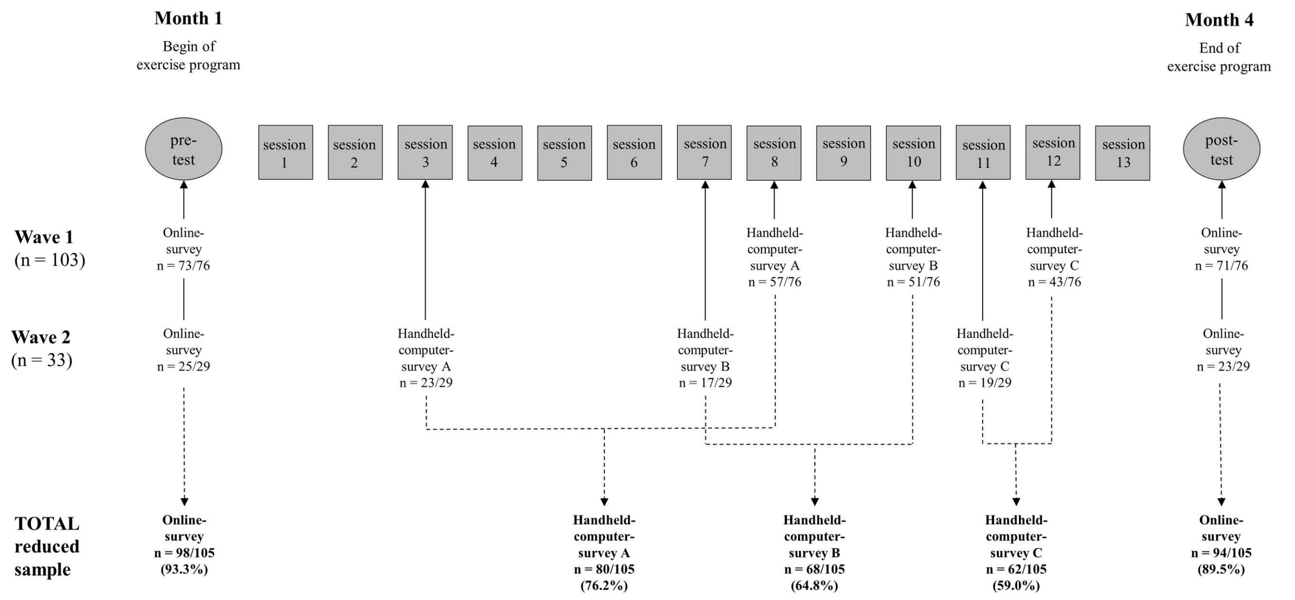

FIGURE 2 | Study design, procedures, and flow of participants. Not considered in the reduced sample: $n = 23$ (no data for at least one handheld-computer-survey; missed all three possible sessions); $n = 5$ (no data for pre-test or post-test).

first approximately between minutes 10 and 15 and the second between minutes 40 and 50. At both measurement points during an exercise session, participants answered questions in respect of two items per affective dimensions. The retest-reliabilities of the two measurements of all affective dimensions within the same exercise session were satisfactory to good (affective valence: $0.62 \leq r \leq 0.75$; calmness: $0.60 \leq r \leq 0.69$; positive activation: $0.57 \leq r \leq 0.59$). For further analyses, we merged the four answers on items per affective dimension during the same exercise session.

We also had two measurements per exercise session for the perceived exertion. These two data items were then combined as well to provide the mean exertion per exercise session. The two perceived exertion scores' correlation during the exercises was satisfactorily strong ($0.46 < r < 0.49$).

Latent Change Scores

The change score for affective attitudes toward exercise (post-test–pre-test) was defined directly as latent variable (Geiser, 2010; Geiser et al., 2010).[2] LC models can be used to compute LC variables that represent the inter-individual differences in intra-individual changes. The advantage of LC models is that the assessment of change in a latent construct can be controlled for measurement errors (Steyer et al., 1997).

The change variable was checked for strong factorial invariance. Factorial invariance is considered to be strong, when not only the (unstandardized) factor loadings of the manifest indicators remain constant across the different measurement times, but also the intercepts of the manifest indicators (Widamann and Reise, 1997). Furthermore, the model was checked for indicator-specific effects. Indicator specificity is seen as a common variance of the measurement error of an indicator across the different measurements (Eid et al., 1999). If indicator-specific effects are not taken into account, models might be misspecified and parameter estimates biased (Reuter et al., 2010).

The LC model was calculated using Mplus 5.21 (Muthén and Muthén, 1998–2010) and applying a maximum likelihood estimator. Missing values for the indicators of affective attitudes (59 missing values, 9.3%) were estimated by means of the full information maximum likelihood (FIML) procedure (Little and Rubin, 2012), as implemented in Mplus. The factor scores for affective attitudes at pre-test as well as for the LC score (post-test–pre-test) were appended to the analysis data set. Thereby, the factor scores can be considered as observed variables in the main analyses.

Two-Level Path Analysis

A two-level path analysis was carried out using Mplus 5.21 and applying a robust maximum likelihood estimator. With this analytic procedure, the hierarchical structure in the data can be taken into consideration. In this way it is possible to split up the total variance into one test person's variance across the three sessions (within-person level) and the inter-individual variance (between-person level). On both model levels, all three affective dimensions were simultaneously taken into account. As the affect dimensions are known to be systematically interrelated (Schimmack and Grob, 2000; Wilhelm and Schoebi, 2007), correlations among these variables are included on both model levels at every given measurement point (pre-session, during session).

[2]A full presentation of the LC model can be found in the Supplementary material.

On the within-person level (level 1), we examined whether perceptions of competence and perceived exertion predict the intra-individual variance of affective responses across various exercise sessions. We controlled these effects for the pre-session values of the respective affective dimensions (autoregressive model), as well as for the situationally perceived fitness.

On the between-person level (level 2), we examined whether perceptions of competence and perceived exertion predict the inter-individual variation of affective responses during physical exercises. The focus was on general, cross-situational effects. The effects were then again controlled for the affective state prior to exercising, as well as for the perceived fitness. Based on already existing results (Sudeck and Conzelmann, 2014), we only tested if perceived fitness predict positive activation and affective valence during physical exercises. However, we did not examine whether perceived fitness predict calmness. All exogenous predictor variables were grand-mean centered.

We analyzed *the direct and indirect effects of exercise experiences on the changes in affective attitude* on the between-person level: firstly, it was tested whether perceptions of competence and the perceived exertion are directly related to changes in affective attitude. Secondly, we tested whether perceptions of competence and the perceived exertion are indirectly related to changes in affective attitude, i.e., imparted via the affective response during exercise. The critical significance level for path coefficients was set conventionally at $\alpha_{crit} = 0.05$ (two-tailed). In order to test mediator effects on the between-person level, we performed bias-corrected bootstrap analyses (MacKinnon et al., 2004). Using this method, confidence intervals were estimated for indirect effects. If a 95% confidence interval does not contain zero, the indirect effect is significant at the 0.05 level.

Prior to carrying-out of the multi-level analysis, it was checked whether the level-specific proportions of the variance favor the application of a multi-level analysis. Intra-class coefficients (ICCs) were calculated for those variables which had been collected several times before, during, or after the exercise sessions. The ICC describes the relation of between-person variance to total variance. The ICC may take a value between 0 and 1. High values indicate a substantial between-person variance and provide an argument in favor of a two-level path analysis (Muthén, 1989).

Figure 2 shows that due to absence some individuals were not able to participate in all handheld surveys in the exercise sessions. In total, the 105 participants of the reduced sample carried out 210 handheld surveys (80 in survey A, 68 in survey B, and 62 in survey C). These handheld surveys were filled out almost completely (see **Table 2**). Missing handheld survey data within the longitudinal data set were estimated again by means of the FIML procedure. In particular, data was imputed on those individuals not able to participate in all handheld surveys in the exercise sessions for reasons of absence. These missing observations were only replaced, however, where we had complete sets for both affective attitude data collections (pre-test and post-test) for the individual concerned. Under these conditions, 61 handheld computer surveys were replaced based on the model (22.5% of 271 observations; 16.1% of the data points of the two-level path model). By imputing the missing observations, and raising the number of observations up to 271, it was possible to strengthen the power of the longitudinal analysis.[3]

The goodness of model fit was assessed through χ^2 tests, comparative fit indices (CFI) and root-mean-square errors of approximation (RMSEA). A good model fit is characterized by a low χ^2 value in relation to the degrees of freedom ($\chi^2/df \leq 2$), as well as a high CFI ≥ 0.97 and a low RMSEA ≤ 0.05. A model fit is considered to be still acceptable when it has a χ^2/df-ratio ≤ 3, as well as a CFI ≥ 0.95 and an RMSEA ≤ 0.08 (Schermelleh-Engel et al., 2003).

RESULTS

Preliminary Analyses

Descriptive Results

Table 2 shows the descriptive values of the exercise experiences (without missing value imputation; 210 observations). All three affective dimensions showed an increase in their mean values from the pre-session measurements to the measurements during the session. The skewness and kurtosis for the affective state measurements ranged from −1 to +1 respectively, with a slight exception for positive activation during exercising. Consequently, the majority of indicators did not diverge from the normal distribution.

The perceived exertion came in with a mean value of $M = 3.80$ ($SD = 1.09$; $Minimum = 1$; $Maximum = 6.5$), indicating a moderate degree of exertion. The clear majority of 85% of the ratings were 'rather light' to 'somewhat hard' ($2.5 \leq \text{Perceived Exertion}_{during} \leq 5.5$). The mean values for perceptions of competence were rather high ($M = 3.96$; $SD = 0.88$; $Minimum = 1$; $Maximum = 5$). Neither the perceived exertion nor perceptions of competence displayed any problematical deviations from the normal distribution (see **Table 2**). The same applied to the perceived fitness.

Preparatory Analyses for the Two-Level Path Analysis

The measuring properties of the LC score for affective attitudes toward exercise were good [$\chi^2(10) = 12.85$; $p = 0.23$; $\chi^2/df = 1.29$, CFI = 0.993; RMSEA = 0.052]. The estimated intercept of the pre-test score was $M = 6.10$ ($SE = 0.19$). The estimated mean value ($M = 1.06$, $SE = 0.21$) and variance ($Var = 3.53$, $SE = 0.61$) of the LC score deviated significantly from zero ($p < 0.05$). It is, therefore, justified to assume inter-individual differences in the LC score. Correlated measuring errors had to be considered for two indicators (AFF1: $r = 0.52$, $p < 0.05$; AFF3: $r = 0.29$, $p < 0.05$). Overall, these results justify the use of the factor scores for affective attitudes at pre-test, as well as for the LC scores as observed variables in the main analysis.

[3] For comparison, we calculated a two-level path analysis exclusively using those cases for which the handheld computer surveys from the exercise sessions were obtained (210 observations). The results were not substantially different.

TABLE 2 | Descriptives and intra-class coefficients of the measures of the handheld computer surveys in the exercise sessions (without missing value imputation, maximum: 210 observations).

	Number of observations	*M*	*SD*	Minimum	Maximum	Skewness	Kurtosis	ICC
Valence pre session	207	4.03	1.14	0	6.0	−0.41	0.02	0.351
Valence during session	210	4.62	0.86	2.0	6.0	−0.63	0.29	0.427
Pos. Activation pre session	207	3.48	1.12	0.5	6.0	−0.03	−0.66	0.308
Pos. Activation during	210	4.18	0.96	0.5	6.0	−0.71	1.31	0.406
Calmness pre session	207	3.56	1.28	0	6.0	−0.28	−0.25	0.531
Calmness during session	210	4.18	0.86	1.5	6.0	−0.13	−0.16	0.423
Perceived exertion	205	3.81	1.08	1.0	6.5	−0.14	−0.21	0.513
Perceptions of competence	210	3.96	0.88	1.0	5.0	−0.80	0.57	0.422
Perceived fitness	208	2.63	0.93	0	5.0	−0.16	0.09	0.701

The ICCs of the used variables are listed in **Table 2**. The ICCs of the affective state values ranged from 0.30 to 0.47. The height of their values suggests that a multi-level analysis is appropriate. The ICC values for affective valence and positive activation during the session were higher than those prior to the session (12–15% higher variance between persons). The ICC values for calmness prior to and during the sessions were considerably closer to each other. Taken together, this intra-individual data indicate that the affective states during exercising were moderately consistent.

Perceptions of competence and the perceived exertion showed similar ICC values to the affective responses during the physical exercises. While for the perceived fitness, we could observe a higher intra-individual consistency.

Two-Level Path Analysis: Indirect and Direct Link between Exercise Experiences and Changes in Affective Attitude toward Exercise

The global model fit of the initial two-level path analysis was acceptable to good [$\chi^2(40) = 78.17$; $p = 0.0003$; $\chi^2/df = 1.95$, CFI = 0.945; RMSEA = 0.059]. However, local model parameter estimates indicated suppression effects for the predictors of changes in affective attitude.[4] Therefore, an alternative model specification appeared necessary in order to achieve a more parsimonious and interpretable model. As the interrelations of the three affect dimensions are theoretically reasonable, it was decided to eliminate critical components of the model as recommended by Maassen and Bakker (2001). For this purpose, non-significant path coefficients were stepwise eliminated from the initial model, which is a common procedure in exploratory path analyses (Pedhazur, 1982; Mertler and Vannatta, 2002). By doing so, three non-significant path coefficients have not been included in the final model (see dotted lines in **Figure 3**).

Figure 3 shows the results of the two-level path analysis for the final model. The global fit of this reduced model was again acceptable to good [$\chi^2(43) = 77.13$; $p = 0.0011$; $\chi^2/df = 1.79$, CFI = 0.951; RMSEA = 0.054].

The relationship between perceived exertion, perceptions of competence and affective responses revealed different results patterns when comparing the two levels of the model: at the within-person level, only perceptions of competence was positively related to the affective response to exercising. In particular, perceptions of competence were associated with within-person variations of positive activation and affective valence across different exercise sessions. At the between-person level, both perceptions of competence and perceived exertion were related to a mean affective response to exercising. The perceived exertion was negatively related to all the affective dimensions. Perceptions of competence were positively associated to calmness during the exercise sessions. In addition, the perceived fitness level predicted within-person variations, as well as between-person variations of positive activation during the exercise sessions.

At the between-person level, direct effects on changes in affective attitude were found for positive activation during the exercise sessions ($\beta = 0.24$), as well as for perceptions of competence ($\beta = 0.24$). The final model on the between-person level revealed one indirect pathway between perceived exertion and changes in affective attitude via positive activation. This indirect path reached statistical significance (−0.14 [CI 95%: −0.26; −0.01]). The other indirect pathway between perceptions of competence and changes in affective attitude via positive activation did not reach statistical significance (−0.04 [CI 95%: −0.12; 0.05]). In total, the model could explain 64.1% of the variance of the LC scores of affective attitudes toward exercise.

DISCUSSION

In the present study, the relationship between exercise experiences and changes in affective attitude was investigated

[4]The following typical pattern of results indicating a suppression effect (Maassen and Bakker, 2001) was observed: firstly, a high negative standardized path coefficient occurred for calmness during the session ($\beta = -0.62$; $SE = 1.08$, $p = 0.57$). Secondly, positive activation during the session had a rather high positive path coefficient ($\beta = 0.40$; $SE = 0.33$, $p = 0.25$) that was higher than the bivariate correlation between positive activation during the session and the change score for affective attitudes (see between-person correlation matrix in the Supplementary material). Thirdly, the residual correlations among the three affective dimensions during the exercise session were very high ($0.83 < r < 0.96$), which correlates with high values in the between-person correlation matrix. Additionally, all standard errors were rather high when compared to the other parts of the two-level path analysis. In detail, the further standardized path coefficients for the prediction of change scores in affective attitudes were as follows: valence during session: $\beta = 0.27$; $SE = 0.67$, $p = 0.68$; perceived exertion: $\beta = -0.11$; $SE = 0.24$, $p = 0.65$; perceptions of competence: $\beta = 0.43$; $SE = 0.37$, $p = 0.25$.

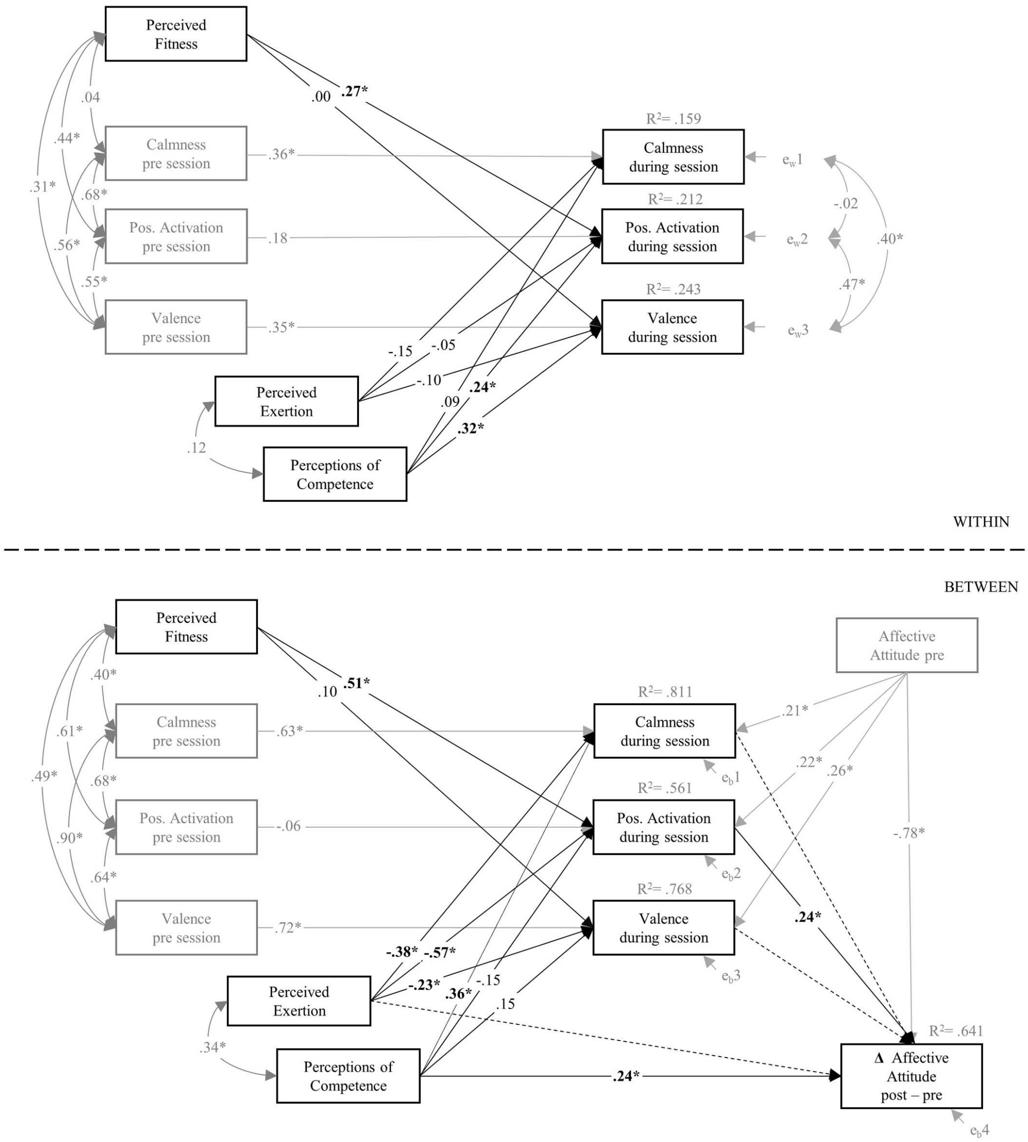

FIGURE 3 | Final results of the two-level path analysis. All reported path coefficients (*$p < 0.05$) are standardized estimates. Non-significant path coefficients for the prediction of Δ affective attitudes were not included in the final model (dotted lines; see main text for further information). For a better overview, correlations among the residuals of the affective states during the exercise session on the between-level of the model (e_b1, e_b2, e_b3) were not illustrated. For the same reason, estimated intercepts, variances, and residual variances were not shown, which were estimated in line with the Mplus 5.21 default settings for the analysis TYPE = TWOLEVEL. At the within-person level, variances of the six exogenous variables as well as the residual variances of the three endogenous variables were estimated. At the between-person level, means and variances for the seven endogenous variables were estimated. Intercepts and residual variances were estimated for the four endogenous variables.

over a period of 13 weeks. The results provide important clues for a more detailed formulation of the transdisciplinary framework model on changing exercise behavior put forward by Bryan et al. (2011).

Our results partially support the assumption of an indirect effect made by Williams (2008), who assumed that cognitive and interoceptive factors predict affective responses during exercising, and that these in turn predict affective attitudes (see **Figure 1**). The results in fact confirm the existence of a chain of effects stretching from perceived exertion via positive activation during exercising to changes in affective attitude. On average, the less strenuous people perceive physical exercise to be, the more awake they will feel during exercise. Those who on average reported more positive activation also showed more improvement in affective attitudes from the beginning to the end of the exercise program. Contrary to this, no indirect relationship between perceptions of competence and changes in affective attitude could be found. In fact, the average level of perceived competence is directly linked to changes in affective attitude without having to be fully reproduced in the affective response to exercise. This direct effect of perceptions of competence illustrates the importance of cognitive factors with respect to changes in affective attitudes toward exercise. Our study thus provides empirical evidence on how affective attitudes to exercising changes depending on interoceptive, affective, and cognitive factors. *In situ* exercise experiences especially may be identified as an important source of changes in affective attitude.

While exercise experiences in existing studies were recorded retrospectively, the data for this study were obtained *in situ* and across several sessions. These procedures made it possible to specify the relationship between individual facets of exercise experiences. Furthermore, they allowed us to substantiate the relationship between exercise experiences and affective attitudes:

(1) It became evident that inter-individual differences in the perceived exertion has a strong negative relationship with affective responses to physical exercise. This is particularly true for the psycho-physiologically determined affective dimension of positive activation as well as for calmness. This result is especially interesting as the intensity of physical strain predominantly ranged from moderate to somewhat hard. According to the dual mode theory, however, inter-individual differences in affective responses should primarily appear with higher intensities (i.e., with strenuous physical exercises, Ekkekakis and Acevedo, 2006).
(2) Moreover, the negative indirect relationship between average levels of perceived exertion on affective attitudes via positive activation during exercise is in line with previous findings on the role of negative physical experiences on affective behavioral predictors. In their diary study, Loehr et al. (2014) identified that body soreness and the perception of exercise as being a chore were negatively associated with positive affective outcome expectancies. The indirect effect in our study indicates that those negative physical experiences which are linked to interoceptive factors during exercise are associated with lower positive activation while exercising. Therefore, the connection between negative physical experiences and affective behavioral predictors may be partly mediated by affective responses to physical exercise.
(3) By means of the two-level analysis, it became evident that the connections between individual exercise experiences are level-specific. While perceived exertion was not connected with intra-individual variations in affective responses, negative relations to the inter-individual variance in affective responses resulted. One possible explanation for inter-individual differences in the affective responses to exercise could be seen in the varying preferences and tolerances for exercise intensities (Ekkekakis et al., 2005). According to this concept, dispositional inter-individual differences exist with respect to self-chosen intensities (preferences) and as to what extent higher strains could be tolerated (tolerance). Such dispositional differences would provide support for a connection between perceived exertion and inter-individual variation in affective responses in the examined range of intensity. Relationships between physical exertion and intra-individual variations, on the other hand, would be expected to a lesser extent.
(4) This study confirms that perceptions of competence are particularly significant for affective responses to exercising (e.g., Rose and Parfitt, 2012). Perceptions of competence not only predicted intra-individual but also inter-individual differences in affective responses when exercising. However, to which affective dimension the responses were attached depends on the level of analysis. Intra-individual variations in both positive activation and valence seem to be positively affected by situational competence experiences; in contrast to that, inter-individual differences in calmness during physical exercises seem more strongly positively associated with the average level of competence experiences. This explorative analysis of specific links between competence experiences and affective dimension would have to be tested and theoretically elaborated in future studies.

Overall, our study supports the assumption that a closer view of exercise experiences contributes to theory development on changes of exercise behavior with a special focus on affective predictors of behavior. For example, the relationships found between average levels of exercise experiences and changes in affective attitude toward physical exercise may, as explained above, be the result of a direct effect. In this way, the robust direct and positive effect of the average level of perceptions of competence on affective attitudes toward exercise demonstrates the importance of the cognitive appraisal of exercise experiences for future affective attitudes toward exercise. However, alternative cognitive mechanisms are also conceivable, such as those regarding the sources of self-efficacy (Samson and Solmon, 2011). It is possible that perceptions of competence, as a kind of mastery experience, have an impact on affective attitudes via self-efficacy (Gellert et al., 2012). Further, it may be assumed that perceptions of competence, as well as low perceived exertion, lead to positive implicit associations with physical exercise. These subconscious associations could in turn be the underlying reason for explicit, affective attitudes (Bluemke et al., 2010). To review alternative effect mechanisms, it is necessary to include further motivational constructs in future examinations [e.g., self-efficacy (Kwan and Bryan, 2010; Schneider and Kwan, 2013); affective outcome expectancies and satisfaction (Baldwin et al., 2013; Loehr et al., 2014)]. In doing so, one could further elaborate on the potential of affective predictors of the adoption and maintenance of physical exercises in comparison to other motivational and volitional predictors of behavior, which were already established in other studies [e.g., outcome expectancies, self-efficacy, intention (Gellert et al., 2012); intention (Mohiyeddini et al., 2009); outcome expectancies, fulfillment of outcome expectancies, action self-efficacy, (Klusmann et al., 2016)].

Limitations

The present study includes some methodical limitations which must be recognized:

(1) In the main analysis, a problem with suppression effects appeared in connection with the prediction of changes in affective attitude. This was probably due to the fact that the model covered three affect dimensions that are systematically interrelated (Schimmack and Grob, 2000). The model's specification had to be slightly modified so that the final model test was no longer, in the strict sense, confirmatory. The results of the final model revealed that average levels of positive activation had the strongest relationship to changes in affective attitude when compared to the other affect dimensions. This pattern of results is in line with the bivariate correlation matrix (see Supplementary material). However, the particular role of positive activation during exercise for the prediction of medium-term changes in affective attitude needs further reinforcement by purely confirmatory analyses in the future.

(2) In our study, exercise experiences were repeatedly obtained *in situ* in natural surroundings, and these were linked to medium-term changes of affective attitude toward exercise. The study thus has a high ecological validity. Nonetheless, it should be noted that the scope of application of the results is limited to *combined* exercise programs in the recreational and health sector. Such exercise programs, in which endurance, strength training, and playful activities are combined in a single session, are very widespread in German-speaking countries (Brehm et al., 2005).

(3) We could not examine whether the study's results varied for the different exercise programs. The sub-samples were too small for a differentiated analysis of the programs' contents and exercise types. For this reason, the findings may, for the time being, only be generalizable to exercises which require physical exertion ranging from moderate to rather strenuous and are carried out in a group and under guidance.

(4) The examined sample included some specific characteristics. We recruited university employees for whom we developed the specific programs. This again limits the generalizability of the findings. Furthermore, the sample was already comparatively active: 50% of the subjects did at least 2 h of physical exercise a week. It would be interesting if future studies could focus more on inactive people or people with increased health risks. Additionally, in the present study more men than women could be considered in the longitudinal analysis. Whether gender represents a moderator for the effect mechanisms remains to be tested.

(5) In our study, it was shown that exercise experiences were moderately consistent at the intra-individual level. Obviously, this degree of consistency was sufficient to make predictions about changes in affective attitude over a 3-months period. What is striking is the fact that the observed intra-individual consistencies in exercise experiences were lower than those reported by Unick et al. (2015). Two reasons for this can be provided: firstly, the physical exercises in the present study were distinctly less standardized. Indeed, the course instructors were instructed to conduct typical sessions. Nevertheless, distinctly larger differences, as far as content and social conditions are concerned were possible between these sessions than in the case of treadmill exercises. Secondly, in the present study, handheld computer surveys were conducted during different weeks in the course of the exercise program. Differences between participation in the first sessions and later sessions of the exercise program may have had an effect on intra-individual differences in the experience of (the same) physical exercises.

(6) Finally, there are some drawbacks in the way the constructs of interest were measured. The questionnaires used to measure perceptions of competence and physical exertion only contained a single item. However, the connections found between the variables suggest that the construct validity of the procedures was satisfactory.

CONCLUSION

Which research desiderata can be deduced from our study? In future studies, the point in time over the course of an exercise program should be systematically considered and examined. Particularly for new participants in exercise programs, an analysis of temporal patterns would be valuable for understanding their experience of physical exercise over the course of the sessions, as such temporal patterns might exhibit a connection to their future exercise behavior. A point in favor of this assumption is the positive relationship between physical fitness and positive activation during exercising (cf. Ekkekakis et al., 2011). Obviously, previous exercise experiences and the connected physical fitness are associated with affective and motivational processes. Thus, future studies should apply systematic recruitment strategies that consider previous exercise behavior in order to be able to analyze the moderating role of previous exercise behavior with sufficient sample sizes of subgroups.

Furthermore, it would be efficacious to use more intensive data acquisition strategies that better reflect the in-depth dynamics of the interplay between different exercise experiences, affective predictors of behavior, and exercise behavior.

Finally, the present study only examined one link of the postulated chain of effects, in the form of exercise experiences and affective attitudes (see **Figure 1**). Future studies should expand this perspective. It would be particularly interesting to take behavior into account as well. Thus, the question might be asked here too, whether affective responses influence exercise behavior indirectly, via motivation – as suggested by Bryan et al.'s (2011) transdisciplinary framework model or whether they have a direct impact on behavior (Williams et al., 2012).

Overall, this study makes clear that perceptions of competence, perceived exertion and affective responses during physical exercise play an important role in affective processes of behavior change. It appears that the average levels of these experiences predict changes in affective attitude during multi-week exercise programs. However, it is recommended that future studies with a higher sample size replicate the main findings obtained for these between-person relationships. For now, our study supports the idea that interventions which aim to change exercise behavior should put more emphasis on exercise experiences in order to address affective behavioral predictors.

AUTHOR CONTRIBUTIONS

GS and AC contributed to the study design. Data collection and data analysis was performed by GS and JS. All authors contributed to the interpretation of the data analysis. GS and JS drafted the manuscript, and AC provided critical revisions. All authors approved the final version of the manuscript for submission. All authors agree to be accountable for all aspects of the work ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: http://journal.frontiersin.org/article/10.3389/fpsyg.2016.00900

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Task Performance and Meta-Cognitive Outcomes When Using Activity Workstations and Traditional Desks

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The purpose of the current study is to compare the effects of light physical activity to sedentary behavior on cognitive task performance and meta-cognitive responses. Thirty-eight undergraduate students participated in the study. The participants used a stationary bicycle with a desk top and a traditional desk while completing two complex cognitive tasks and measures of affect, motivation, morale, and engagement. The participants pedaled the stationary bicycle at a slow pace (similar in exertion to a normal walking pace) while working. The results indicated that cognitive task performance did not change between the two workstations. However, positive affect, motivation, and morale improved when using the stationary bicycle. These results suggest that activity workstations could be implemented in the work place and in educational settings to help decrease sedentary behavior without negatively affecting performance. Furthermore, individuals could experience a positive emotional response when working on activity workstations which in turn could help encourage individuals to choose to be more physical active during daily activities.

Keywords: : **sedentary lifestyle, physical activity, cognitive performance, affect, morale**

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INTRODUCTION

It is well known that regular physical activity has positive health benefits such as improved cardiovascular functioning, decreased body weight, and a more positive outlook (Warburton et al., 2006). Regular moderate to vigorous physical activity alone; however, does not seem to be the answer to long-term good health. Even in people exercising regularly, the amount of sedentary behavior is related to chronic disease (Owen et al., 2009) and physical frailty (Song et al., 2015). As such, it is important to consider factors that may contribute to rates of physical activity (Hagströmer et al., 2014).

Most adults are generally inactive (Sisson and Katzmarzyk, 2008) with the amount of physical activity decreasing with age and with lack of understanding of the health benefits of exercising (Mullineaux et al., 2001). There is also increasing evidence that to better understand the effects of activity levels we must consider how activity is incorporated throughout the day (Tudor-Locke and Schuna, 2012). One example is in sedentary occupations where physical activity is typically infrequent (Smith et al., 2014). It is possible that many adults working in a sedentary occupation could have difficulty finding time to exercise each day. Because the work day takes up approximately half of all waking hours, working a full-time job can leave many people with little time to engage in physical activity during leisure time on a daily basis. Consequently, the amount of physical activity when working becomes an important component of health-related behaviors.

Sedentary adults report that they are not more active due to a variety of reasons such as exercise being too risky, exercise being too much effort, and exercise being inconvenient (Vanden Auweele et al., 1997). Owen et al. (2011) suggest that the influence of the place or environment must also be considered to understand sedentary behavior. Furthermore, an Ecological Momentary Assessment of physical activity and sedentary behavior could provide a means to better measure activity across the day (Dunton et al., 2012). Although there is considerable evidence suggesting the need for better examining levels of physical activity across the day, few studies have examined how the design characteristics of work desks may impact daily functioning.

Studies suggest that individuals who hold desk-based or computer-based jobs have higher levels of sedentary behavior (Hill and Peters, 1998; Hill et al., 2003). Work place programs have been initiated to counter this trend. Most of these work place programs are designed to increase physical activity through encouraging the worker to walk around or use stairs more during the work day. Although many work place programs may decrease sedentary behavior to some extent, they often require the worker to purposely leave the workstation, something that many workers could find difficult to do. Furthermore, work place interventions requiring that workers be active away from their workstations are fundamentally limited since they are focused on available time during the work day when employees can choose to be away from their normal sedentary workstation.

One method to reduce sedentary time is to integrate activity workstations in the work place allowing individuals to work on a desk top or a computer while being physically active. Activity workstations allow individuals to complete desk-based or computer-based tasks while moving at a low level of physical exertion usually through walking at a normal pace or by pedaling relatively slowly. Although activity workstations are a relatively new idea, they offer some useful benefits over more traditional work place interventions of encouraging employees to simply move more since the employees are not required to choose between working and being physically active. Furthermore, studies suggest that using activity workstations can increase the level of energy expenditure in the individual (Tudor-Locke et al., 2014) and may also have health benefits (Carson et al., 2014). Activity workstations may also have a positive benefit on stress and affect (Sliter and Yuan, 2015). These effects on meta-cognitive measures, such as stress and affect, are of particular interest when considering implementing workstations into settings that are normally sedentary in nature. Using workstations to provide a positive meta-cognitive effect of being physically active could encourage engaging in physical activity and, as such, increase physical activity across the lifespan.

Relatively little research has investigated the effects of using activity workstations on performance or on psychological variables (Rhodes et al., 2012). Some evidence suggests that activity workstations can result in performance decrements on tasks such as typing speed and motor skills (Straker et al., 2009; Ohlinger et al., 2011) while other studies have concluded that working on an activity workstation did not negatively affect performance (Carr et al., 2014). Furthermore, little research has examined the effect of activity workstations on meta-cognitive factors. Two studies have concluded that using activity workstations resulted in decreases in reported stress (Edelson and Danoffz, 1989; Sliter and Yuan, 2015) and beneficial effects on affect (Sliter and Yuan, 2015). Sliter and Yuan (2015) also suggested that the type of workstation (walking versus cycling) could affect psychological benefits of using the workstations.

The purpose of the current study is to examine how individuals perform while riding on a stationary bike with a desk top (FitDesk) and while seated at a normal desk (traditional desk) as well as their perceptions of working on the tasks at the two types of desks. We hypothesize that the participants will perform equally well on the FitDesk and on the traditional desk when completing complex cognitive tasks. We also hypothesize that the participants will report improved affect, motivation, morale, and engagement, when working on the FitDesk than the traditional desk.

MATERIALS AND METHODS

Participants

The participants were 38 university students [average age: 19.64 ($SD = 1.05$), 11 males, 27 females] who were in good physical and mental health and did not report tobacco use. The experimental protocol was approved by the university Institutional Review Board and all participants signed an informed consent form before the experimental study. All participants were compensated $25 for completing the study as well as credit for completion of a research component of an introductory psychology class.

Procedures

This study compares performance when using a FitDesk (Revo Innovations LLC, Antioch, TN, USA) to performance when sitting at a traditional desk. The FitDesk is a silent, stationary bike with a desk top which allows the user to work on a laptop or tablet while pedaling the bike. Participants were required to ride at a comfortable slow pace similar in exertion to a normal walking pace when using the FitDesk. In the current study, participants completed the tasks once while engaging in light physical activity at the FitDesk and once when seated at a traditional desk.

Prior to the onset of the experimental sessions, participants were required to complete an adaptation period using the FitDesks in the university library for two one-hour periods, while completing tasks of their choice. The participants signed in and out using a QR code and recorded the odometer reading on the FitDesk before and after their session using a provided form. After the adaptation period, the participants completed two experimental sessions at least 24 h apart and within one week of the adaptation period. Each testing session lasted approximately 45 min and took place between 8:00 AM and 7:00 PM. The participants could choose which time of the day to attend the testing sessions. Most participants (82%) chose the same time of the day for both testing sessions to fit the sessions into their course schedule.

The participants completed two cognitive tasks at their assigned desk (FitDesk or traditional desk) followed by a set of subjective surveys during each testing session. The conditions (FitDesk or traditional desk) and the two cognitive tasks were counterbalanced across the testing dates.

Cognitive Measures

The Law School Admission Test (LSAT) includes a standardized test of verbal logical reasoning. The questions are based on information provided in a short passage. The reader is required to determine the correct answers based on the presented material. The questions evaluate the ability of the individual to analyze and critically evaluate information and arguments as well as offer insight into their ability to apply concepts or rules in a variety of situations (Law School Admission Council). The logical reasoning section of the LSAT exam has been reported to have 86% reliability (Wainer and Thissen, 1996). For the current study, participants were asked to complete as many questions as possible from a maximum of 19 questions within a 25-min period. The task was verbally described to participants at the start and participants were provided an opportunity to ask questions. Two versions of the logical reasoning test were used.

Raven's Standard Progressive Matrices (SPM) test is often used as a test of nonverbal reasoning (Lynn et al., 2004). The SPM is a measure of an individual's ability to extract patterns from several pictures of geometric designs and generate new ideas about complex situations (Raven, 2000). High levels of both internal consistency and test-retest reliability have been reported on the SPM (Raven et al., 2000). The current study used two sets of SPM figures each containing 18 items. The SPM test was verbally described to participants before beginning the task and participants were provided an opportunity to ask questions. The participants were asked to correctly complete as many items as possible in 10 min.

Subjective Measures

After the cognitive tasks, the participants filled out a short set of subjective surveys. They first completed Borg's Rating of Perceived Exertion Scale (RPE; Borg, 1982, 1990). The RPE provided a subjective measure of exercise intensity. A meta-analysis found that the RPE is related to physiological measures of physical exertion with validity coefficients ranging from 0.57 to 0.72 (Chen et al., 2002). The participants rated their level of physical exertion on a scale from 0 (nothing at all) to 10 (very, very strong).

Next the participants completed the positive and negative affect schedule (PANAS). The PANAS contains 20 affective-related words and uses a 5-point Likert scale from not at all to extremely. Watson et al. (1988) report that the PANAS has high internal reliability for the positive (Chronbach's α of 0.86–0.90) and negative (Chronbach's α of 0.84–0.87) scales.

The participants then filled out a single item question on motivation followed by the five-item Morale Scale evaluating energy, drive, enthusiasm, eagerness, and morale while completing the testing session (Britt et al., 2013). The questions were assessed on a 5-point Likert scale from very low to very high. The Morale Scale has been shown to have a Cronbach's α of 0.93 (Britt et al., 2013).

Last, participants completed the Engagement Scale using a 5-point Likert scale from strongly disagree to strongly agree (Britt et al., 2010). Participants responded to six items assessing subjective performance, absorption, and attention. The Engagement Scale has been shown to be a predictor of performance in academic settings (Britt et al., 2010).

Statistical Analysis

Individual responses that were greater than three standard deviations away from the mean for the item were removed from data analysis. This occurred only with the RPE where three subjects' were removed from the analysis. The LSAT and SPM were scored as percent correct. The PANAS was scored based on established metrics to create a positive and negative score (Watson et al., 1988). The responses on the Morale and Engagement Scales were averaged for each scale (Britt et al., 2010, 2013).

SPSS 22 (SPSS Inc., Chicago, IL, USA) was used for all data analyses. A repeated-measures MANOVA was used to determine if there were differences between the FitDesk and traditional desk conditions.

TABLE 1 | Descriptive statistics: means, standard deviations, and 95% confidence intervals.

Variable	*M*	*SD*	95% CI lower	95% CI upper
LSAT				
FitDesk	51.52	17.91		
Traditional Desk	49.03	18.88	−2.67	7.66
Raven's SPM				
FitDesk	79.53	15.72		
Traditional Desk	84.65	11.07	−10.64	0.41
Rating of perceived exertion				
FitDesk	2.01	1.08		
Traditional desk	0.48**	0.99	1.18	1.88
Positive PANAS				
FitDesk	28.26	5.84		
Traditional desk	23.47**	5.81	2.69	6.89
Negative PANAS				
FitDesk	11.71	1.58		
Traditional desk	12.18	3.17	−1.53	0.58
Motivation				
FitDesk	3.26	0.64		
Traditional desk	2.87*	0.81	0.12	0.67
Morale				
FitDesk	3.16	0.62		
Traditional desk	2.65**	0.68	0.25	0.78
Engagement				
FitDesk	3.75	0.53		
Traditional desk	3.61	0.58	−0.06	0.33

*$p = 0.005$; **$p < 0.001$.

RESULTS

The descriptive results for each variable (means, standard deviations, and 95% confidence intervals) are shown in **Table 1**. There were no significant differences in performance on the LSAT or the SPM when comparing performance on the FitDesk to performance at the traditional desk.

Participants reported greater physical exertion when using the FitDesk [$F(1, 34) = 78.386$, $p < 0.001$, and $\eta_p^2 = 0.697$]. Participants reported significantly greater positive affect on the PANAS [$F(1,34) = 19.542$, $p < 0.001$, and $\eta_p^2 = 0.365$] when using the FitDesk but did not report a difference on the negative affect. Participants also reported higher levels of motivation [$F(1,34) = 5.79$, $p = 0.009$, and $\eta_p^2 = 0.187$] and higher levels of morale [$F(1,34) = 12.010$, $p = 0.001$, and $\eta_p^2 = 0.261$] when working on the FitDesk. In contrast, there was no difference in engagement between the conditions.

DISCUSSION

The current results suggest that the use of the FitDesk positively affects subjective states while not decreasing complex cognitive performance as measured by the LSAT logical reasoning and the SPM. More specifically, using the FitDesk resulted in increased levels of positive affect, motivation, and morale. In addition, when using the FitDesks, participants reported greater physical exertion than when using the traditional desk. However, the average subjective exertion level for both workstations remained quite low (FitDesk = weak; traditional desk = very, very weak).

The current results supported our first hypothesis that working on the FitDesk would not negatively affect complex cognitive performance. The lack of significant effects on logical reasoning and fluid intelligence tasks are consistent with previous findings that activity workstations do not impact cognitive functioning (Ohlinger et al., 2011). This suggests that activity workstations could be used in the work place and educational settings without fear of negatively affecting complex cognitive performance. This finding could have a profound effect in work places and other environment settings where people are required to sit for long periods of time (e.g., waiting rooms, airports). As suggested by Proper et al. (2011), interventions to reduce sedentary behavior are needed in many environments in modern society. Furthermore, attempting to separate work from other aspects of life may not be a meaningful way to evaluate health-related behaviors or long-term health risks (Panelli and Gallagher, 2003). Instead it is important to consider physical activity throughout the day and provide recommendations that can be implemented in modern societies that are increasingly requiring sedentary work. Because sedentary behavior has become common practice in many work places, implementing activity workstations could decrease sedentary activity while allowing workers to complete their responsibilities.

The current results partially supported our second hypothesis that working while on the FitDesk would improve affect, motivation, morale, and engagement. We found a significant improvement in positive affect, motivation, and morale but not in engagement as measured by Britt et al. (2010) engagement scale. Improvements in positive mood states and morale are seen following exercise (Tate and Petruzzello, 1995; Reed and Ones, 2006; Liao et al., 2015) suggesting that light activity when using workstations may have similar effects as moderate to vigorous exercise. The current results indicate that light physical activity on a cycling workstation while completing cognitive tasks can improve positive affect and morale. These findings contrast with a study concluding that cycling workstations resulted in reduced satisfaction (Sliter and Yuan, 2015). However, the cycling workstations used in the Sliter and Yuan study were not FitDesks and instead were separate cycle units set up near a desk top which seemed to bring about participant discomfort. In contrast, FitDesks are ergonomically designed to counter this possible effect with the desk top located at a comfortable distance from an adjustable height seat.

It is important to note that the use of the FitDesks in the current study had a positive impact on the emotions and feelings of the participants. The participants were more positive, had greater motivation, and better morale when completing required complex cognitive tasks while being active and working on the FitDesk than while being inactive and working at a traditional desk. This suggests that individuals could enjoy using activity workstations, such as the FitDesk, at work or in educational settings where environments currently encourage sedentary activity. This positive feeling from individuals could help increase the amount of physical activity that individuals choose to participate in daily. In addition, because the light physical activity can be completed while doing tasks, this makes more time available for physical activity during the day when many individuals say that they do not have time for a stand-alone exercise period. Additional research is required using activity workstations to better document how well activity workstations can be integrated into different sedentary environments. More research is also needed on additional meta-cognitive factors such as acceptance of using activity workstations and the impact of completing tasks on activity workstations as well as potential mediating variables.

The improvement in positive affect seen in the current study could have important work place implications. Positive affect is associated with improved problem solving and decision making which can lead to flexible and creative cognitive processing (Isen, 2001) and can help facilitate coping mechanisms and healthy behaviors in individuals (Aspinwall, 1997). Improved positive affect and motivation are also related to responsible work behavior (Isen and Reeve, 2005) while increased motivation is related to persistence (Glastra et al., 2004). The results from the current study suggest that light physical activity could produce positive mental states while completing necessary tasks which in turn could improve over-all morale in a variety of work settings.

It is interesting to note there was no significant change in negative affect on the PANAS while there was an improvement in positive PANAS when using the FitDesk. Previous studies have shown that negative affect is not impacted by age (Mroczek and Kolarz, 1998) or by sleep deprivation (Pilcher et al., 2015). Furthermore, research suggests that negative affect does not change in persons focused on goal-driven behaviors

(Mogg and Bradley, 1998). Previous research also indicates that steady, lower levels of negative affect are related to an increase in life satisfaction (Pilcher, 1998). These results suggest that negative affect may be a more stable phenomenon than positive affect. As such, it seems unlikely that negative affect would be easily altered by light physical activity.

The current study has some limitations. Participants were not screened for physical fitness levels prior to the start of the study. However, the participants were healthy and young and they reported a low level of physical exertion ranging from weak to very, very weak. Because of the low level of activity, the physical fitness level is less of a concern in the present study. Future studies can be designed to include a measure of physical fitness in research examining light physical activity to address this issue. In addition, the current study used college students as participants which could make it difficult to generalize the findings to older adults. However, student and nonstudent samples tend to agree about 80% of the time (Highhouse and Gillespie, 2008) suggesting that the negative effects of student sampling is limited.

CONCLUSIONS

The present study is among the first research studies examining performance and meta-cognitive outcomes when using an activity workstation versus a traditional desk. The results indicate that light physical activity on a stationary bicycle had no detrimental effect on performance on complex cognitive tasks but did result in an improvement in meta-cognitions related to daily functioning, affect, and decision making. Furthermore the improvement in affect, motivation, and morale, suggests that light activity when working on an activity workstation may help encourage light physical activity when completing necessary tasks as well as desired activities (e.g., TV and video games). It is also possible that a positive feeling associated with physical activity could encourage individuals to be more physically active, thus increasing physical activity across the lifespan. Together these findings support the potential of implementing activity workstations in the workplace and in educational settings. Additional research is needed examining the effects of activity workstations in different settings and with different populations. However, the current results suggest that making activity workstations more available could help decrease the amount of sedentary behavior experienced by many adults with little disruption to their daily work. Implementing activity workstations in settings where individuals are expected to sit (e.g., the workplace, educational settings, waiting rooms, and airports) could decrease sedentary activity without negatively affecting performance and could have positive effects on affect, motivation, and morale.

AUTHOR CONTRIBUTIONS

JP conceived of the study with input from VB. JP provided oversight for VB in developing the methods for the study. VB carried out the data collection and initial data analysis under direction by JP. VB wrote an early draft of the manuscript. JP revised and completed the writing of the manuscript. All authors read and approved the final manuscript.

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Understanding the Reasons behind Anticipated Regret for Missing Regular Physical Activity

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Anticipated affective reactions to missing physical activity (PA), often labeled anticipated regret, has reliable evidence as a predictor of PA intention and behavior independent of other standard social cognitive constructs. Despite this evidence, the sources of regret are understudied and may come from many different reasons. The purpose of this study was to theme the reasons for why people responded to anticipated regret over missing regular PA for 2 weeks. Participants were a random sample of 120 university students who were primed on the public health definition of PA, completed measures of regret, and were asked to list their reasons for regret. Ninety-five percent of participants expressed that they would regret not being active and gave a total of 357 reasons. The dominant theme ($n = 247$; 69%) was a missed opportunity to obtain the benefits of PA, followed by shame/guilt for not being able to follow-through with one's goals or self-categorized role ($n = 99$; 28%) with a final theme of perceived pressure from others ($n = 11$; 3%). From a practical perspective, the diversity of these reasons suggest that more clarity on the source of regret should be present in assessment, while building from both attitude and identity theories may help understand how regret motivates PA in future intervention.

Keywords: anticipated affective reactions, theory of planned behavior, exercise, affective judgments, thought listing

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INTRODUCTION

The health benefits of regular physical activity (PA) are extensive and include reducing the risks of acquiring over 25 chronic conditions (Warburton et al., 2007). Despite this irrefutable evidence, few people engage in enough PA to reap even minimal health protective gain (Troiano et al., 2008; Colley et al., 2011). Clearly, PA promotion is of paramount concern to public health.

The use of sound theoretical approaches to understanding PA has been advocated in order to provide organized frameworks for targeted intervention (Rhodes and Nigg, 2011). Much of this theoretical research has applied social cognitive approaches that emphasize the considerable rational benefits of performing PA and enhancing control over performance (Fishbein et al., 2001). One aspect that has been under-developed in past social cognitive approaches within the PA domain is the potential role of affective processes (Rhodes et al., 2009b; Ekkekakis et al., 2013; Williams and Evans, 2014; Rhodes and Kates, 2015).

Affective expectations of enjoyment are reliable correlates of PA that add additional variance to our understanding of the behavior (Rhodes et al., 2009b; Teixeira et al., 2012). Among these sets of expectations, however, there is also evidence that anticipated affective experience from performing the behavior, may be different from the anticipated affective reaction to not performing the behavior (Conner et al., 2015). These anticipated affective reactions to abstention are typically labeled anticipated regret (Abraham and Sheeran, 2003). Our literature review of anticipated regret and PA identified seven studies that have applied the construct (Conner and Abraham, 2001; Abraham and Sheeran, 2003, 2004; Jackson et al., 2003; Sheeran and Abraham, 2003; Sandberg and Conner, 2011; Wang, 2011). Of the two experimental studies (Abraham and Sheeran, 2004; Sandberg and Conner, 2011), both showed that modifications to anticipated regret increased PA, albeit modestly. Furthermore, four of the five studies to evaluate the predictive capability of anticipated regret, showed it had a contribution to explaining intention independent of social cognitive factors in the theory of planned behavior (Conner and Abraham, 2001; Abraham and Sheeran, 2004; Sandberg and Conner, 2011; Wang, 2011). Thus, the construct has fairly reliable evidence in the PA domain as a predictor of PA.

Conner et al. (2015) propose the theoretical process for how anticipated regret affects PA is via self-conscious emotions (e.g., guilt; Giner-Sorolla, 2001). These negative emotions are anticipated pre-emptively and serve as motivation to avoid the outcome (Simonson, 1992). Interestingly, this also reflects the self-regulating processes for behavioral performance in identity theory (Stryker and Burke, 2000). Identities are considered components of a self-concept, organized by standards on how one views themselves in a given role (Burke, 2006). These standards act as comparators to actual behavior, and are activated in relevant situations where identities are either aligned or mismatched with one's behavior. Discrepancies challenge an identity and provide negative affect that serves to motivate identity consistent behavioral actions (Stets and Burke, 2000; Price Tangney, 2003), a premise with support in the PA domain (Flora et al., 2012). Thus, prompting anticipated regret for missing PA may serve as activation of ones identity for health and well-being, or goal-driven achievement. Currently, no research has examined the reasons behind responses to PA anticipated regret, so the mechanisms remain unexamined.

While the suggested mechanisms for anticipated regret by Conner et al. (2015) seem sensible, there may also be other reasons less tied to self-conscious emotions or personal standards. For example, regret may be from mere expectations of missed opportunities. If one values the outcome of a particular behavior, failure to perform the behavior may be regretted even if there is no personal shame or guilt involved. In this case, anticipated regret may be a better measure of anticipated value of the behavior and add conceptually to the outcome expectation or attitude concept (Fishbein et al., 2001). Another possibility for regret may align more with feelings of external guilt associated with not performing the PA. This notion is commensurate with introjected regulation in self-determination theory (Deci and Ryan, 2000), where one feels a sense of obligatory duty to perform the behavior to appease others but also seems aligned with subjective norm and the perceived pressure one may feel from outside social forces (Ajzen, 1991). Given these are all plausible alternatives to the reasons for experiencing anticipated regret, a formal examination would be helpful to better articulate the construct and its antecedents.

Therefore, the purpose of this study was to theme reasons for why people respond to moderate and vigorous intensity PA anticipated regret using thought listing procedures. We also sought to explore whether participants who were regularly active had different responses from those who were active. Based on the rationale and theorizing from Conner et al. (2015), we hypothesized that most people would anticipate regretting PA due to self-conscious reasons or personal standards. Nevertheless, we hypothesized that some people may regret PA as a missed opportunity to improve health and well-being or from external pressures.

MATERIALS AND METHODS

Participants and Procedures

Participants were students enrolled in the 2014 winter term at the University of Victoria, Canada. A list of all 100- and 200-level classes at the university were collected ($k = 667$). Classes were stratified by year and 10 different Faculties and assigned a random number between 0 and 1. The list was sorted by the random number in descending order. Within each year and Faculty, two classes with random numbers closest to 1 were selected to be contacted. Nineteen 100- and 200-level classes were randomly selected to be contacted through the university email system. The content of the email asked potential participants to complete a short survey on beliefs and motives for PA. The link for the survey was provided at the end of the email.

After informed consent, participants were asked to complete a measure of PA. On the next page of the survey, we then defined PA to create a context for subsequent questions. PA was defined as aerobic activities at least 150 min per week during free time that was in the moderate intensity (brisk pace) or higher range. Regular brisk walking was provided as an example of how one could achieve this level of PA. We also included resistance training, defined as any work with weights (squats, deadlift, bench press, curls, etc.) and other strength exercises (push-ups, pull-ups, and sit-ups) done during free time (i.e., not occupation, school, or housework). Participation in resistance training was defined as at least two bouts per week to align with Canadian public health guidelines (Tremblay et al., 2011). Following this definition of PA participants completed the anticipated regret question and thought listing procedure.

Measures

Anticipated Regret

To elicit the reasons behind anticipated regret, participants were asked to consider the definition of PA noted above and then asked if they would feel regret if they did not engage in this amount of activity over the next 2 weeks. The participants were then directed to a forced dichotomy answer of a yes or no response. The phrase used in this question was identical to prior items used to asses anticipated regret in the PA domain (Abraham and Sheeran, 2003, 2004; Sheeran and Abraham, 2003), yet the forced dichotomization was created in this study to help elicit reasons for participant choices.

The thought listing measure included the statement "considering your answer on the last question, please list the main reasons why you generally think you will regret, or not regret engaging in regular PA." Five short open lines followed this statement, so that participants could express their views. This follows similar guidelines to general thought listing methodology (e.g., Petty and Cacioppo, 1986).

Behavior

Participants reported the frequency and duration of participation in mild, moderate, and vigorous intensity PA using the Godin Leisure Time Exercise Questionnaire (GLTEQ; Godin and Shephard, 1985; Godin et al., 1986). The GLTEQ was modified to correspond with current public health guidelines for moderate and vigorous intensity activity. The GLTEQ is a valid and reliable measure of PA and is one of the most commonly applied self-report measures of PA (Jacobs et al., 1993).

Analysis Plan

Following sample descriptives, the main hypotheses were evaluated using thematic coding to categorize reasons for anticipated regret. These data were coded as total counts per theme (Petty and Cacioppo, 1986), similar to prior research (Rhodes and Blanchard, 2007). Specifically, a judge was trained to code the thoughts, identify the valence of each thought (positive negative) and to identify themes. A theme was created if at least 3% ($n = 10$) of the sample made reference to it as a reason for their reports of regret, however, we anticipated possible themes of missed opportunity (outcome values), self-conscious guilt, and external pressures. After primary coding, a second coder independently categorized reasons as well as identified the valence of each reason. The inter-rater reliability for the categories ($\alpha = 0.89$) and valence ($\alpha = 1.00$) were acceptable. Finally, responses were sub-coded by whether participants reported meeting Canadian PA guidelines (Tremblay et al., 2011) in order to describe the proportions of respondents by theme. To provide some falsification to this examination, we considered failure to align with a theme as outright rejection of a hypothesis, while <50% endorsement of a theme as only moderate evidence for the hypothesis. We subsequently considered differences between active and inactive participants higher than 10% as minimally meaningful (Cohen, 1992) for the exploratory analyses.

RESULTS

Sample Descriptives

Participants were 120 university students ($M_{age} = 20.64 \pm 2.88$; 55% female) with 2.35 ± 1.80 years of university education. Fifty-seven percent of participants were accumulating enough moderate to vigorous PA to meet the Canadian PA guidelines. Nearly the entire sample ($n = 114$; 95%) of participants said they would feel regret if they were not physically active over the next 2 weeks. Overall, participants provided a mixed range of one ($n = 13$; 11%), two ($n = 28$; 25%), three ($n = 28$; 25%), four ($n = 14$; 12%), or five ($n = 31$; 27%) reasons for regret.

Reasons for Feeling Regret

Thematic analysis of the reasons why respondents would feel regret are provided in **Table 1**. In total, participants cited 378 reasons. Of these, 357 reasons fit into themes; the remaining 21 reasons were not classified because they were too diverse to theme (<10 reasons with similar content). Five themes emerged from the thought listing procedure, although these were also grouped as three dominant over-arching themes.

Missed Opportunity

The most frequent over-arching theme was an expression of the missed opportunities to achieve the benefits of regular PA ($n = 255$; 69%). In this theme, participants did not express

TABLE 1 | Reasons for anticipated regret of physical activity (PA; *N* = 357; Active = 202, Inactive = 155).

Themes	*n*	%	Examples
Missed opportunity	247	69	
Positive expectations	138	39	"I feel better after training" "I know it will improve my mood after" "I want to be fit"
Active	88	25	"Because I want to look good" "I enjoy walking and running"
Inactive	50	14	"It is good for my health"
Negative expectations	109	31	"Gaining weight" "I would lose my gains; Lose strength" "I feel unhealthy physically"
Active	56	16	"I would have a harder time falling asleep" "I would feel bored"
Inactive	53	15	"Missed opportunity to improve my health"
Personal shame	99	28	
Evaluative	89	24	"I would be disappointed in myself" "I would feel lazy"
Active	44	12	"I would feel guilty" "I feel like I am failing myself"
Inactive	45	13	"I would feel like I let myself down" "Disappointing I can't even stick to my goals"
Descriptive	10	3	"I'm an athlete" "I am an active person"
Active	9	2	"I am a runner"
Inactive	1	0	
External pressures	11	3	
Others	11	3	"My trainer will not be happy" "My tennis partner would kill me"
Active	9	2	"My team depends on my athletic capabilities" "I have a responsibility to exercise partner"
Inactive	2	1	"Will let down my team"

Inactive participants defined as <150 weekly minutes of moderate + strenuous intensity PA.

a sense of personal regret or self-conscious shame, but did express concern for missing what they perceive the behavior bestows on them. The most frequent responses included positive expectations ($n = 138$; 39%). This was endorsed by 44% of those meeting guidelines and 32% of those not meeting guidelines. Responses were most commonly linked to the affect domain such as "I feel better after training," or "I enjoy walking and running" but many positive expectations also included distal outcomes of PA such as "it is good for my health" or "I want to lose weight." Negative expectations in the form of a missed opportunity were the second highest reported reasons for regret ($n = 109$, 31%). This was endorsed by 28% of those meeting guidelines and 34% of those not meeting guidelines. These were generally a re-framing of the positive expectations such as "I would lose the gains I have made," "I would be bored," "I would miss the chance to be healthy," or "I would have a harder time falling asleep."

Personal Shame

The next dominant theme for feeling regret reflected responses that linked to the individual's perceived role in the performance of PA. This included 99 responses (28%) across two sub-themes. The most common sub-theme was an expression of personal shame and disappointment ($n = 89$; 25%). This was endorsed by 22% of those meeting guidelines and 29% of those not meeting guidelines. This theme included responses such as "I would be disappointed in myself," "I would feel like I was failing myself," "it sucks to set goals and then not keep them," and "I would feel like I let myself down." The second sub-theme, considerably smaller in expression ($n = 10$; 3%), was more descriptive of the personal role one has with regular PA as an identity. This was endorsed by 4% of those meeting guidelines and 1% of those not meeting guidelines. Responses included "I'm an athlete," "I am an active person," or "I am a runner."

External Pressures

The final theme that emerged featured reasons surrounding external pressures for PA. These reasons included no expression of missed opportunity or personal concern but a sense of regret because that others would be letdown by inaction ($n = 10$; 3%). This was endorsed by 4% of those meeting guidelines and 1% of those not meeting guidelines. Examples for this theme included "My trainer will not be happy," "My team depends on my athletic capabilities," and "My exercise partner would shred me."

DISCUSSION

Anticipated regret is a reliable predictor of future intentions and behavior (Sandberg and Conner, 2008; Conner et al., 2015), but the sources of regret are poorly understood. Thus, the purpose of this study was to theme reasons for why people responded to regret over missing regular PA. Based on the rationale and theorizing from Conner et al. (2015), we hypothesized that most people would anticipate regretting PA due to self-conscious reasons or personal standards. This hypothesis had some support. Almost a third of the reasons given for regret were aligned with personal self-conscious reasons. These were most often expressed in evaluative (e.g., I will feel like I am letting myself down) terms, thus supporting theorizing that negative emotions are anticipated pre-emptively and serve as motivation to avoid the outcome (Simonson, 1992).

A small number of reasons were also framed in terms of an identity in PA (e.g., I am an athlete). From a conceptual standpoint, future research should examine the interplay between PA identity and anticipated regret, as they may be linked via these negative emotions (Stets and Burke, 2000; Price Tangney, 2003). Manipulations where participants are asked to consider not exercising for several weeks have shown that those with exercise identities experience heightened negative affect compared to those who identify less with exercise (Strachan and Brawley, 2008; Strachan et al., 2009) and this includes personal self-conscious emotions (Flora et al., 2012). The manipulations are very similar to the phrasing of anticipated regret questions, so it seems reasonable to assume that identity may be a partial source of these anticipated affective reactions. As PA identity is also a reliable predictor of intention and behavior (Rhodes et al., 2016) an examination of these constructs may be helpful in developing theoretical depth. Interestingly, the only study to evaluate both concepts in the same model showed that anticipated regret was not related to intention independent of identity, although they shared only a modest relationship with each other (Jackson et al., 2003). Clearly more research is needed to make any judgments on how these constructs inter-relate.

A rather surprising finding from our results was that the dominant theme for anticipated regret was about the missed opportunities that regular PA bestows. These reasons were not framed in terms of any self-conscious emotions but merely that participants would miss out on an enjoyable experience, a chance to get outdoors, the potential to keep healthy, or to maintain/improve one's figure. While, we did hypothesize that some regret would be from this missed opportunity, we did not expect such an overwhelming 69% of responses to reflect this aspect.

These results are important because they shed light on how people are perceiving regret and where this may fit in terms of our current theories. Much of regret may be overlapping with the conceptual aspects of attitudes/behavioral beliefs (Fishbein et al., 2001). Interestingly, this was also the only area where there was a marked difference in our exploratory analyses of these themes separated by past activity status (i.e., meeting PA guidelines). Active participants reported even more positive expectations than inactive participants, which is likely a consequence of stronger overall behavioral beliefs toward PA (McEachan et al., 2011). It may be that anticipated regret questions are helpful measures of these concepts because they underlie the personal value component. That is, when people are asked to answer whether PA is important or beneficial in traditional attitude questions, they may be answering in a more colloquial sense than when asked if they would regret not reaping these benefits. Typically, asking about the expectancy and value of PA in a straightforward approach has not yielded much predictive benefit above mere expectancies (Gagne and Godin, 2000; Rhodes et al., 2009a), yet an expression of this using regret, which may personalize the response, could be useful. Anticipated regret for PA does tend to correlate with attitude in the medium to large range (Conner and Abraham, 2001; Abraham and Sheeran, 2003, 2004; Jackson et al., 2003; Sheeran and Abraham, 2003; Sandberg and Conner, 2011; Wang, 2011), underscoring its shared variance. Furthermore, experimental manipulations of anticipated regret are centered upon the attitudinal domain (either through exposure to attitude questions or educational material; Abraham and Sheeran, 2004; Sandberg and Conner, 2011) and so this follows a logical sequence that anticipated regret may better reflect the personalized value of PA than standard attitude questions. Regardless, the divisive reasons for regret, between self-conscious emotions and missed opportunities, suggest that more clarity is needed in future anticipated regret measurement. We recommend that these reasons (e.g., I would regret not engaging in PA because I would feel I am letting myself down; I would regret not engaging in PA because I will have missed a chance to improve my health) be included in future assessments to help tease out the different sources of regret.

Finally, a small number of reasons (3%) for regret reflected less personal shame or missed opportunity than external social pressures. These included letting key others down (e.g., teammates, workout partner) who seemed tied to the respondent's social network. The relatively low number of responses for these external pressures suggests this is not a frequent source of regret and would not explain much of its strong predictive value in intention and behavior. This is commensurate with subjective norm in the theory of planned behavior and introjected regulation in self-determination theory as neither construct is a reliable predictor of PA (McEachan et al., 2011; Teixeira et al., 2012). Still, the above noted recommendation to clarify the reasons for regret during assessment would help parse out external social obligations from the more frequent sources of regret in future research.

Despite the interesting and novel findings of the study, there are limitations that warrant mention. First, the sample herein is comprised of undergraduate students so these findings may not generalize to older participants. Second, our single item measure of anticipated regret may not have yielded as much from the thought-listing procedure as a multi-item measure, so replication with the more typical two- and three-items measures will help for future research on this matter. Third, the procedures in this study ask participants to consider hypothetical regret which may be different from the actual feelings of experienced regret. While hypothetical regret would still seemingly serve as the motivation for pre-emptive behavioral enactment, it would be interesting to also examine whether actual regret mirrors the expectations of participants. Fourth, the thought-listing procedure was effective at prompting a host of reasons for regret, but other procedures such as a think-aloud protocol (Fonteyn et al., 1993) may help triangulate these results.

AUTHOR CONTRIBUTIONS

RR conceived of the topic, wrote the paper, and assisted in the analyses. CM collected these data and engaged in the primary analyses as well as assisting in the writing.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: http://journal.frontiersin.org/article/10.3389/fpsyg.2016.00700

Data sheet 1 | Reasons for anticipated regret.

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MINI REVIEW
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The Acute Relationships Between Affect, Physical Feeling States, and Physical Activity in Daily Life: A Review of Current Evidence

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Until recently, most studies investigating the acute relationships between affective and physical feeling states and physical activity were conducted in controlled laboratory settings, whose results might not translate well to everyday life. This review was among the first attempts to synthesize current evidence on the acute (e.g., within a few hours) relationships between affective and physical feeling states and physical activity from studies conducted in free-living, naturalistic settings in non-clinical populations. A systematic literature search yielded 14 eligible studies for review. Six studies tested the relationship between affective states and subsequent physical activity; findings from these studies suggest that positive affective states were positively associated with physical activity over the next few hours while negative affective states had no significant association. Twelve studies tested affective states after physical activity and yielded consistent evidence for physical activity predicting higher positive affect over the next few hours. Further, there was some evidence that physical activity was followed by a higher level of energetic feelings in the next few hours. The evidence for physical activity reducing negative affect in the next few hours was inconsistent and inconclusive. Future research in this area should consider recruiting more representative study participants, utilizing higher methodological standards for assessment (i.e., electronic devices combined with accelerometry), reporting patterns of missing data, and investigating pertinent moderators and mediators (e.g., social and physical context, intensity, psychological variables). Knowledge gained from this topic could offer valuable insights for promoting daily physical activity adoption and maintenance in non-clinical populations.

Keywords: exercise, mood, accelerometry, experience sampling, ecological momentary assessment, free-living

INTRODUCTION

Despite the health-promoting effects of physical activity (Penedo and Dahn, 2005), most individuals are physically inactive in their daily lives (Bauman et al., 2011). A large body of research has suggested that physical activity can boost emotional well-being (i.e., the “feel good” effect; Reed and Ones, 2006). Several behavioral theories have suggested that individuals will engage in behaviors that provide pleasure (e.g., Bentham, 1962), or from which they anticipate a positive affective response (e.g., Mellers, 2000). Accordingly, people would be expected to engage in continued physical activity over time if they experienced a boost in positive affect but to exercise less across time if negative affect resulted. Yet, research is lacking on the extent to which these pleasure theories underlie individual motivations to engage in daily physical activity.

Until recently, most studies investigating the acute associations between affective states and physical activity have been conducted in controlled laboratory settings (e.g., performing pedaling exercise in a lab). Although lab studies allow researchers to have a precise control of the physical activity session (i.e., the intensity and duration), and an exact timing of when to assess affective states, the external validity of findings from these studies is questionable since both behaviors and emotion reactions could differ dramatically between lab-based and naturalistic settings (Gunes et al., 2008; Bussmann et al., 2009). One of the reasons is that in the laboratory, conditions are prescribed to participants, while in the real world, individuals have natural preferences and choices about situations they seek and avoid (Wilhelm and Grossman, 2010). Unveiling the acute relationships between affective states and physical activity in free-living situations might help to shed light on how people make decisions to engage in physical activity during their everyday lives. Moreover, most lab-based studies focus on affective responses either during or after physical activity. Whether affective states also act as precursors to engaging in physical activity is less clear. A better understanding of whether affective states predict physical activity (and vice versa) could have important implications for promoting everyday physical activity, especially long-term physical activity maintenance.

Previous studies on this topic usually use a variety of terms such as "affect," "emotion," and "mood" to describe people's psychological experience. While psychologists have distinct definitions for each of these term (e.g., "emotion" is considered to be a more generic term than "affect" since it could include other attributes such as physiological changes; Lazarus, 1991), researchers from other fields (e.g., behavioral science and public health) sometimes use these words interchangeably. In addition, some physical activity researchers use the term "physical feeling states" to capture sensory experiences such as energy and fatigue that may be distinct from positive/negative affective states (Dunton et al., 2014). For this review, all terms used to describe the immediate emotional states that a person feels at any given moment were included, and were hereafter referred to as either "affective states" or "physical feeling states" to reflect their momentary nature.

The current review aimed to answer the following questions among non-clinical populations: (1) Do affective and physical feeling states predict subsequent physical activity levels in free-living situations? (2) Does free-living physical activity lead to improvement in subsequent affective and physical feeling states (e.g., increases in positive affect, decreases in negative affect)?

MATERIALS AND METHODS

Literature Search Strategy

Literature searches were conducted for articles that were published in English using Medline, PsycINFO, and Google Scholar. Articles published prior to November 2, 2015 were included. The following keyword combinations were used: Physical Activity or Exercise and Mood or Emotion or Affect (see Supplementary Table S1 for sample full search strategy used for OVID Medline). Titles and abstracts identified through the search process were reviewed to identify relevant articles.

Inclusion and Exclusion Criteria

Studies were included in this review that (1) examined the short term relationship between free-living physical activity and some type of affect or feeling measure; and (2) involved participants who were free from psychological- or physical-disorders. Free-living physical activity was defined as any physical activity that is not performed in a controlled environment or under extensive monitoring by research personnel for research study purposes.

Studies were excluded if: (1) the physical activity was performed in a controlled lab or research setting; (2) the time frame for the physical activity and affect relationship under examination was greater than 1 day; (3) affect was only measured during physical activity, or the temporal relationship between physical activity and affect was not clear (e.g., study only compared differences in affective state between active vs. non-active episodes); and (4) physical activity or affect were only assessed at one time point.

Data Extraction

The data extraction procedure involved two stages. First, a coding form was developed for general data extraction to identify study characteristics including source, participants, methods, and results. Second, risk of bias assessment for each study was performed based on four domains including selection bias, confounders, data collection methods, and withdrawals and drop-outs, adapted after the Quality Assessment Tool for Quantitative Studies (National Collaborating Centre for Methods and Tools, 2008). Two reviewers performed the data extraction procedure independently. All discrepancies between reviewer's ratings were resolved through discussions that led to a consensus.

RESULTS

Literature Search

The initial searches yielded 3,745 potentially relevant articles. After title and abstract scanning, 211 articles were retrieved for further evaluation. One hundred and two studies were excluded because physical activity was not measured in a free-living situation. Forty-two studies were excluded because the association between physical activity and affect was observed over a time frame greater than 1 day. Twenty-eight studies were excluded because physical activity was only assessed at one time point (e.g., one aerobic class session). Another 25 studies were excluded because the temporal precedence of either physical activity or mood was not clear (e.g., examined the association between average daily physical activity level and average daily mood) or because of the cross-sectional study design. A total of 14 unique studies were eligible for the final review (see **Supplementary Figure S1**).

Study Characteristics

Table 1 summarizes the general characteristics of the 14 included studies. A majority of the studies ($N = 12$) utilized an experience sampling or Ecological Momentary Assessment (EMA) method (for more details about these two methods, see papers by Scollon et al., 2003; Shiffman et al., 2008, and Ebner-Priemer and Trull, 2009). Among these studies, 9 used electronic devices (e.g., a PDA) to deliver surveys and collect responses, and the other three used paper-pencil surveys with beepers to signal alerts. Only 6 studies used an objective measure (i.e., accelerometer) of physical activity. Seven studies used a self-reported physical activity instrument. One used gym attendance (based on a computerized scan of membership card for gym entry) as a proxy for physical activity and cross-checked with self-reported exercise tracking forms.

Quality Assessment

Table 2 shows the results of the quality assessment for each study. Selection bias was generally high (rating of weak) since most studies used convenience samples (e.g., college students) instead of randomly selected participants from the general population (only one study recruited this way). All studies used appropriate statistical methods (e.g., multilevel modeling) to control for clustering within individuals and some studies additionally controlled for other within-person confounding variables. Data collection methods were rated for both affect and physical activity assessment, and one studies received a weak rating due to the use of unestablished assessment tools. Three studies received a weak rating on withdrawals since they did not report any information regarding study drop-outs or missing data. Overall, three studies received a strong global rating and three studies received a weak global rating.

Short-Term Associations of Affective States with Subsequent Physical Activity

Only 6 of the 14 studies examined whether affective states predicted subsequent physical activity. Three studies found a significant positive association between positive affect and subsequent physical activity (Carels et al., 2007; Dunton et al., 2009; Schwerdtfeger et al., 2010), two found positive but non-significant association (Mata et al., 2012; Dunton et al., 2014), and one found a significant negative association (Wichers et al., 2012). In these studies, the length of accumulated physical activity levels being examined ranged from 30 min after assessment of positive affect (Schwerdtfeger et al., 2010; Dunton et al., 2014) to the whole day after affect assessment in the morning (Carels et al., 2007). Overall, based on findings from these studies, there is preliminary evidence for positive affective states predicting subsequent physical activity.

Five studies examined the association between negative affect and subsequent physical activity. One study found that higher negative affect was associated with less physical activity within a subsequent 30-min window (Dunton et al., 2009). None of the other four studies found a significant association (Schwerdtfeger et al., 2010; Mata et al., 2012; Wichers et al., 2012; Dunton et al., 2014). Therefore, preliminary evidence suggests that negative affective state is not necessarily an antecedent of physical activity in free-living situations.

Two studies also examined the association between physical feeling states (i.e., energy and fatigue) and subsequent physical activity. One study found that feeling more energetic led to more subsequent physical activity, and feeling more tired was associated with less subsequent physical activity (Dunton et al., 2014) in children. The other study did not find any significant association among middle-aged to older adults (Dunton et al., 2009). Overall, the evidence for physical feeling states predicting subsequent physical activity is very limited and inconclusive.

Short-Term Associations of Physical Activity with Subsequent Affective States

Twelve studies examined the effects of physical activity on subsequent affective state. Eight out of the 11 studies found a significantly positive association between physical activity and subsequent positive affective state. In these studies, the time frame of the association ranged from immediately after (Gauvin et al., 1996; Carels et al., 2007; LePage and Crowther, 2010), to 3 h after a physical activity bout/session (Guérin et al., 2013). Three studies did not find a significant relationship (Mata et al., 2012; von Haaren et al., 2013; Kanning et al., 2015), and one did not report the significance test result (Annesi, 2002). Thus, based on these results, there is some consistent evidence for physical activity improving subsequent positive affective state.

Of the five studies that tested the effects of physical activity on subsequent negative affective state, two found a significant decrease in negative affect after engaging in physical activity (Gauvin et al., 1996; LePage and Crowther, 2010), two found no significant association (Mata et al., 2012; Wichers et al., 2012), and one found no significant association at within-person level but a significantly negative association at between-person level (Dunton et al., 2014). Therefore, the current evidence for physical activity decreasing subsequent negative affective state is mixed and inconclusive.

Seven studies also tested effects of physical activity on subsequent physical feeling states (e.g., energetic and calmness/tranquility). Five studies found a significant positive association between physical activity and subsequent feeling of energy (Gauvin et al., 1996; Kanning et al., 2012, 2015; Kanning, 2013; Dunton et al., 2014), one did not find a significant association (von Haaren et al., 2013), and one did not report the significance test result (Annesi, 2002). Thus, there is some evidence for physical activity increasing subsequent feeling of energy. Three studies found a significant decrease in calmness (Kanning et al., 2012, 2015; Kanning, 2013), one found a significant increase (Gauvin et al., 1996), one did not find a significant association (von Haaren et al., 2013), and one did not

TABLE 1 | Characteristics of included studies.

First author, year	Country	*n*‡	Participant characteristics	Mean age (range)	Female %	Affect assessment	Affect assessment frequency	Physical activity assessment
Kanning et al., 2015	Germany	69	A randomized sample of older adults	60.1(50–70)	51%	A six-item short scale adapted from the Multidimensional Mood Questionnaire (measures energetic arousal, valence, and calmness, with two bipolar for each).	When accelerometer detected a volume of physical activity that surpassed a predefined activity threshold (activity >220 mili-g; 10-min moving average) or fell below a predefined inactivity threshold for 3 days.	Activity level measured from accelerometer for 3 days.
Dunton et al., 2014	United States	119	Children from low to middle income households	N/A(9–13)	51%	Rating on eight adjectives assessing PA (two items), NA (four items), energy (one item), and fatigue (one item).	Randomly 3–7 times a day during preprogrammed intervals for 4 days.	Activity level measured from accelerometer for 4 days.
von Haaren et al., 2013	Germany	29	Inactive college students	21.3(N/A)	N/A	A six-item short scale adapted from the Multidimensional Mood Questionnaire (measures energetic arousal, valence, and calmness, with two bipolar for each).	Randomly every 2 h between 10 am and 10 pm for 2 days.	Activity level measured from accelerometer for 2 days.
Guérin et al., 2013	Canada	63	Active mothers	42.6(N/A)	100%	PA subscale (10 items) from the Positive and Negative Affect Scale (PANAS).	Before, after, and 3-h after each self-reported moderate-to-vigorous physical activity session for 2 weeks.	Self-reported type, intensity, and duration of exercise.
Kanning, 2013	Germany	87	College students	24.6(N/A)	54%	A six-item short scale adapted from the Multidimensional Mood Questionnaire (measures energetic arousal, valence, and calmness, with two bipolar for each).	Randomly every 45 min for 14 h.	Activity level measured from accelerometer for 1 day.
Kanning et al., 2012	Germany	44	College students	26.2(N/A)	48%	A six-item short scale adapted from the Multidimensional Mood Questionnaire (measures energetic arousal, valence, and calmness, with two bipolar for each).	Every 45 min for 14 h.	Activity level measured from accelerometer for 1 day.
Mata et al., 2012	United States	53	Volunteers recruited from community	25.4(N/A)	70%	Rating on 11 adjectives assessing PA (four items) and NA (seven items) guided by PANAS.	Every 90 min (up to eight times each day) for 7–8 days.	Self-reported activity level (Godin) at each electronic survey prompt.
Wichers et al., 2012	Belgium	504	Female twins from the general population	27(18–46)	100%	Ratings on 10 adjective assessing PA (four items) and NA (seven items) guided by PANAS.	Randomly every 90 min (up to 10 times each day) for 5 days.	Self-reported one item of activity level on a 7-point Likert scale at each electronic survey prompt.
Schwerdtfeger et al., 2010	Germany	124	Volunteers recruited through campus	31.7(18–73)	52%	Rating on 11 adjectives assessing PA (six items) and NA (five items).	Every 1 h for 1 day (about 12 total for each participant).	Activity level measured from accelerometer for 1 day.
LePage and Crowther, 2010	United States	54	Regularly active college students	19.1(N/A)	100%	PA (10 items) and NA (10 items) subscales from the PANAS – Expanded Form (PANAS-X).	Randomly four times a day and following each self-reported exercise bout for 10 days.	Self-reported type and amount of exercise.
Dunton et al., 2009	United States	23	Inactive adults aged 50+ years recruited from community	60.7(50–76)	70%	Rating on 10 adjectives assessing PA (one items), NA (seven items), energy (one item), and fatigue (one item).	Four fixed times (7:45 am, 11:45 am, 3:45 pm, and 7:45 pm) per day for 2 weeks.	Self-reported type and duration of exercise.
Carels et al., 2007	United States	36	Obese participants recruited from community	49.3(N/A)	89%	A single-item, unidimensional 10-point feeling scale ranging from "very negative mood" to "very positive mood."	Daily diary filled out each morning and before bedtime, and before and after each self-reported exercise bout for 8 weeks.	Self-reported type, intensity, and duration of exercise.
Annesi, 2002	United States	69	Fitness center members from community	37.9(21–60)	71%	Exercise-induced Feeling Inventory (12-item) assessing positive engagement, revitalization, tranquility, and physical exhaustion.	Before and after each self-reported exercise bout for 6 weeks across 14 weeks.	Fitness center attendance cross-checked with self-reported exercise tracking forms.
Gauvin et al., 1996	United States	86	Recruited through YMCA from community	32.9(N/A)	100%	Exercise-induced Feeling Inventory (12-item) and 4 adjectives for PA, 5 adjectives for NA.	Randomly four times a day, and before and after self-reported exercise bouts for 6 weeks.	Self-reported intensity of physical activity (that lasted at least 20 min).

TABLE 2 | Quality assessment of included studies.

Study	Selection bias	Confounders[1]	Data collection methods[2]	Withdrawals and drop-outs	Global rating[3]
Kanning et al., 2015	Moderate	Strong	Strong	Strong	Strong
Dunton et al., 2014	Weak	Moderate	Strong	Strong	Moderate
von Haaren et al., 2013	Weak	Moderate	Strong	Weak	Weak
Guérin et al., 2013	Weak	Moderate	Strong	Strong	Moderate
Kanning et al., 2013	Weak	Moderate	Strong	Strong	Moderate
Kanning et al., 2012	Weak	Moderate	Strong	Weak	Weak
Mata et al., 2012	Moderate	Strong	Strong	Strong	Strong
Wichers et al., 2012	Strong	Strong	Moderate	Strong	Strong
Schwerdtfeger et al., 2010	Weak	Strong	Strong	Weak	Weak
LePage and Crowther, 2010	Weak	Moderate	Moderate	Strong	Moderate
Dunton et al., 2009	Weak	Moderate	Moderate	Strong	Moderate
Carels et al., 2007	Moderate	Strong	Weak	Moderate	Moderate
Annesi, 2002	Weak	Moderate	Moderate	Strong	Moderate
Gauvin et al., 1996	Weak	Moderate	Moderate	Strong	Moderate

[1]*Studies were rated as strong on confounders (i.e., sufficiently controlled for potential confounding variables) if a multilevel modeling method was used (i.e., controlling for multiple observations within-person) and other within-person confounding variables were included (e.g., activity taking place 15 min before the affect assessment, pre-activity affect and feeling states, pleasantness of activity, and time of day). Studies were rated as moderate if only one of the two methods of controlling for confounding was used.* [2]*Affect assessment and physical activity assessment were rated separately for data collection methods for each study. Studies were rated strong for affect assessment if they used an established scale with known reliability and validity. Studies were rated as strong for physical activity assessment if an objective measure was used (e.g., accelerometer);as moderate if a valid and reliable self-reported measure was used; and as weak if no validity or reliability of the self-reported measure was provided.* [3]*Studies were rated as strong if they received three Strong ratings with no Weak ratings; as moderate if less than three Strong and one Weak ratings; as weak if two or more Weak ratings.*

report significance test result (Annesi, 2002). Thus, the effect of physical activity on subsequent feelings of calmness is mixed and inconclusive.

DISCUSSION

To the authors' knowledge, this review is one of the first attempts to systematically examine the bi-directional acute relationship between affective and physical feeling states and free-living physical activity among non-clinical populations. The fact that only a limited number of studies were included in our review suggests that more research is needed to better understand the links between affective states and free-living physical activity, especially whether and how affective and physical feeling states might act as a predictor for daily physical activity. Findings from this review show that positive affective states could potentially lead to being more physically active subsequently, although this positive relationship did not always reach significance. Further, most studies did not find a significant relationship between negative affective state and subsequent physical activity. Physical feeling states (i.e., energy and fatigue) might also be a predictor for free-living physical activity, although current evidence only showed this effect among children but not older adults. Overall, current literature suggests that people's affective states, especially positive affective states (e.g., happy, excited), might be a predictor of free-living physical activity. Similar to the findings from lab studies (e.g., Reed and Ones, 2006), results from this review show that physical activity seems to improve immediate subsequent positive affective states and enhances feelings of vitality in people's daily lives. However, engaging in physical activity may not necessarily decrease subsequent negative affective states (e.g., feeling stressed, sad, anxious) among non-clinical populations.

Limitations of Current Studies

The present review used a modified version of Quality Assessment Tool for Quantitative Studies to assess study quality across all included studies, which addressed aspects (e.g., selection bias, data collection methods, withdrawals/missing data) that could be important for future studies to consider when investigating the acute relationships between affective and physical feeling states and physical activity in free-living settings. First, most of the reviewed studies used a convenience sample (e.g., undergraduate students from a Psychology class). Therefore, findings from these studies might not be representative of the general population, or high-risk populations for physical inactivity. Future studies on this topic would be strengthened by recruiting more representative (e.g., diverse age, ethnicity, and socioeconomic background) study participants from community-based samples.

Secondly, only six studies used both an electronic device to deliver and record momentary mood assessment, and an accelerometer to measure physical activity levels; which is considered as the highest methodological standard to use for investigating within-person associations between momentary affective states and physical activity in everyday lives (see the position statement by Kanning et al., 2013). Further, in order to capture a more representative sample of people's behaviors, the total monitoring period should also be longer (e.g., more than 1 day).

Finally, none of the reviewed studies that used electronic devices provided information regarding level of data loss or missing data. As reported by Dunton et al. (2012), missing data from EMA could be due to non-compliance (i.e., non-response or non-wear) by the participants, or could be due to technical problems with the devices (e.g., device lost/damage, battery drain, app failed to initiate). A better understanding of the reasons for data loss could provide important insights for future studies that may want to adopt technology-based devices (e.g., whether researchers should put more effort into ensuring participant compliance or enhance device reliability). Therefore, when reporting results, researchers should consider providing such information.

Future Directions

Future research in this area could be informed through the exploration of potential moderators of the acute relationships between affective states and physical activity, such as co-occurring contextual exposures. Studies have suggested that adults are more likely to be physically active if their significant others are also exercising with them (Giles-Corti and Donovan, 2002), and are less active when they are at home indoors compared with other locations (Liao et al., 2015). Further, being with other people may enhance positive affective response during physical activity compared to alone (Dunton et al., 2015), and more positive affective states occurred when outdoors and with others than when indoors and alone (Dunton et al., 2011). More studies on this topic are needed to examine the multi-way interactions among physical activity, affective, and physical feeling states, and physical and social contexts to find an optimal contextual setting for physical activity engagement. In addition, other psychological variables could influence both affective/physical feeling states and physical activity levels. For instance, one of the reviewed studies showed that the more the physical activity was autonomously regulated, the more energetic individuals felt afterwards (Kanning et al., 2012), and the other study found that higher momentary self-efficacy led to a higher physical activity level (Dunton et al., 2009). It would be worthwhile to investigate how fluctuations in these psychological variables might acutely influence affective states and physical activity or moderate their relation. For example, does positive affective response to physical activity change global self-efficacy or outcome expectancies over time, leading to more physical activity?

Further, intensity and duration of physical activity may influence the affective responses to physical activity (e.g., the dual-mode model; Ekkekakis, 2005). However, research in this area has mainly been performed in controlled laboratory settings. Only two of the reviewed studies examined the role of perceived intensity and both found that higher intensity activities led to a greater increase in positive affect afterwards (Carels et al., 2007; Guérin et al., 2013). In addition, since sedentary behavior is associated with increased risks of metabolic syndrome and cardiovascular disease (Edwardson et al., 2012; Wilmot et al., 2012); and there are studies demonstrating the metabolic-health benefits from breaks in sedentary time (e.g., some light activity in-between sedentary time; Owen et al., 2010). It would be also be a promising direction to examine how reduced sedentary time may affect affective states in future studies.

Lastly, although observational studies carried out in free-living settings have the strengths of demonstrating ecological validity and temporal precedence of the associations between affective states and physical activity, these studies are limited in their ability to draw causal conclusions. Future studies should seek out methods to test these associations using experimentally based approaches such as randomly assigning individuals to affect or activity conditions and measuring subsequent free-living behavior.

In summary, more research is needed to elucidate the bi-directional relationships between affective and physical feeling states and physical activity, especially whether and how affective and physical feeling states might acutely predict subsequent activity in people's everyday lives. More research in these areas would be valuable for physical activity adoption and long-term physical activity maintenance strategies.

AUTHOR CONTRIBUTIONS

YL conceived of the study, conducted the literature search, performed data extraction, and drafted the manuscript. ES performed data extraction. GD conceived of the study, participated in its design, and helped to draft the manuscript. All authors read and approved the final manuscript.

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SUPPLEMENTARY MATERIAL

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FIGURE S1 | Flowchart for literature search.

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Affect and Subsequent Physical Activity: An Ambulatory Assessment Study Examining the Affect-Activity Association in a Real-Life Context

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Traditionally, cognitive, motivational, and volitional determinants have been used to explain and predict health behaviors such as physical activity. Recently, the role of affect in influencing and regulating health behaviors received more attention. Affects as internal cues may automatically activate unconscious processes of behavior regulation. The aim of our study was to examine the association between affect and physical activity in daily life. In addition, we studied the influence of the habit of being physically active on this relationship. An ambulatory assessment study in 89 persons (33.7% male, 25 to 65 years, $M = 45.2$, $SD = 8.1$) was conducted. Affect was assessed in the afternoon on 5 weekdays using smartphones. Physical activity was measured continuously objectively using accelerometers and subjectively using smartphones in the evening. Habit strength was assessed at the beginning of the diary period. The outcomes were objectively and subjectively measured moderate-to-vigorous physical activity (MVPA) performed after work. Multilevel regression models were used to analyze the association between affect and after work MVPA. In addition, the cross-level interaction of habit strength and affect on after work MVPA was tested. Positive affect was positively related to objectively measured and self-reported after work MVPA: the greater the positive affect the more time persons subsequently spent on MVPA. An inverse relationship was found for negative affect: the greater the negative affect the less time persons spent on MVPA. The cross-level interaction effect was significant only for objectively measured MVPA. A strong habit seems to strengthen both the positive influence of positive affect and the negative influence of negative affect. The results of this study confirm previous results and indicate that affect plays an important role for the regulation of physical activity behavior in daily life. The results for positive affect were consistent. However, in contrast to previous reports of no or an inverse association, negative affect decreased subsequent MVPA. These inconsistencies may be—in part—explained by the different measurements of affect in our and other studies. Therefore, further research is warranted to gain more insight into the association between affect and physical activity.

Keywords: multilevel regression model, accelerometer, ecological momentary assessment, diary, habit, mood

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INTRODUCTION

Explaining and predicting health behavior and health behavior change has long been an important topic in health psychological research, and several theoretical models and approaches have been developed and used (Rothman, 2000; Schwarzer, 2008). Most models assume that health behaviors such as physical activity are consciously regulated by cognitive, motivational, and volitional processes (Gibbons et al., 2009). These commonly used models only modestly explain and predict health behavior (Williams, 2008; Rhodes and Yao, 2015). Recently, several authors have introduced new perspectives such as unconscious influences on behavior and the role of affect (Williams, 2008; Schwarzer, 2014; Sniehotta et al., 2014). Health behaviors such as physical activity and eating are behaviors of daily life, which are not necessarily regulated by conscious processes such as planning (Sheeran et al., 2013). Everyday life health behaviors are regulated in two ways (Kremers et al., 2006): via cognitive, motivational, and volitional processes and via processes triggered automatically by external (situational or environmental) features or internal cues (affects or emotions; Bargh and Chartrand, 1999; Slovic et al., 2005). According to Russell (2003) affect is conceptualized as "a neurophysiological state that is consciously accessible as a simple, nonreflective feeling" (p. 147). Other terms used for describing this concept are "mood"or "feeling" (Russell, 2003). Affects play an important role in regulating human behavior and influence behavioral reflexes, motivational processes underlying various behaviors as well as complex decision making (Russell, 2003; Naqvi et al., 2006). Automaticity of behavioral reactions is adaptive and beneficial, and humans would not be able to accomplish daily life if even simple decisions and actions would involve deliberate thoughts (Bargh and Chartrand, 1999; Chartrand and Bargh, 1999). Habits represent such an automated pathway to action (Gardner, 2014).

Affect and Physical Activity

Although several studies have examined the relationship between affect and physical activity (Williams, 2008), affective processes preceding behavior have received less attention in health psychological research than cognitive, social, and environmental determinants. Exercise, affective response, and exercise adherence are presumably part of a causative chain. While to date the link between affective response and adherence has received little attention, many studies have examined the link between exercise and affective responses. Overall, these studies have shown that physical activity influences positive (but not negative) affect, and engaging in physical activities has psychological benefits (Schwerdtfeger et al., 2010). However, this relationship is not that simple, it depends on intensity and duration of physical activity (Ekkekakis, 2005).

Most previous studies have focused on the unidirectional relationship between affect and physical activity. Considering the role of affects as internal cues triggering automatic processes of behavior regulation suggests the possibility that the relationship between affect and physical activity is bidirectional. However, to date only few studies have investigated affect as predictor of subsequent physical activity (Schwerdtfeger et al., 2010; Liao et al., 2015). Overall, higher positive affect appears to predict higher subsequent physical activity levels but the extent of negative affect does not seem to predict the subsequent physical activity level. Only one study revealed a significant association of negative affect and subsequent physical activity (Dunton et al., 2009).

Abbreviations: MVPA, moderate to vigorous physical activity.

Habit and Physical Activity

A habit is defined as a learned sequence of situational cues that activate a specific goal or end-state and prompt a behavior (Verplanken and Orbell, 2003; Gardner, 2014). Core components are cue-dependence, automaticity, and conditioned stimulus-response association (Orbell and Verplanken, 2010). Thus, habit reflects the impulsive and automatically triggered pathway to behavior. Performing habitual behavior requires little awareness, consciousness, and cognitive effort and is hence highly efficient (Verplanken and Orbell, 2003). Moreover, habits persist even if conscious motivation wanes (Gardner, 2014). In the health behavior context habits have an ambivalent character. Habitual behavior is stable and resistant against "disturbances" which is positive for healthful but negative for unhealthful behaviors, in terms of behavior change interventions (Neal et al., 2006; Verplanken and Wood, 2006; Orbell and Verplanken, 2010). A strong habit to exercise regularly reflects that this behavior is automatically triggered via internal or external cues. Little awareness and cognitive effort is necessary to perform physical activities which makes it less vulnerable to situational disturbing internal or external conditions.

Previous studies have shown that habit strength is related to health behaviors such as healthy diet or physical activity. A systematic review and meta-analysis revealed medium to large effect sizes for the correlation between physical activity habits and physical activity behavior (Gardner et al., 2011). Most studies concentrated on exercise, sedentary behavior, and active commuting, and only few studies focused on overall physical activity (Gardner et al., 2011; Thurn et al., 2014). Moreover, most observational and correlational studies have used subjective measures of physical activity compared to few longitudinal or experimental studies using objective measures of physical activity (Gardner, 2014; Thurn et al., 2014).

Considering the importance of habits and affect in behavior regulation in daily life, these constructs should be examined in a real-life context. Hence, an ambulatory assessment study may be appropriate for studying within person associations between habit strength, affect, and physical activity.

Ambulatory Assessment

To address the relationship between affect and physical activity the characteristics of these complex constructs must be considered and their interplay during short time intervals in daily life must be understood (Shiffman et al., 2008). Affective states underlie dynamic fluctuations across days and even within-days and may be influenced by situational and environmental factors (Stone et al., 1996). Studies using single, retrospective self-reported ratings of affect did not address this association adequately because of limitations such as recall bias (Shiffman et al., 2008). Ambulatory assessment of people in their natural environments can be performed using different methods including momentary self-reports, ecological momentary assessments, and observational and physiological methods (Trull and Ebner-Priemer, 2013). These methods have several advantages: affective states within persons during a week in the participants' natural environment can be assessed repeatedly using electronic diaries, and physical activity and self-reported affective states can be measured simultaneously with accelerometers and mobile devices, respectively. Hence, these methods allow analyzing the interrelationship between affect and physical activity in daily life.

Aims and Hypotheses

The first aim of this study was to examine the association between positive and negative affect and subsequent moderate-to-vigorous physical activity (MVPA) in a real-life context. Ambulatory assessment was used to assess participants' MVPA and affect in their natural environment. We used electronic diaries to assess affective states and self-reported MVPA repeatedly within persons and accelerometers to objectively monitor MVPA. We hypothesized that positive affect is positively related to subsequent MVPA while negative affect is negatively related to subsequent MVPA. The second aim was to investigate the effect of habit strength on MVPA in daily life. We hypothesized that a strong habit to be physically active is associated with more time in MVPA during weekdays. Moreover, we assumed that habitual physical activity could protect this behavior against barriers or low self-control resources (Neal et al., 2013). Therefore, we hypothesized that a strong habit to perform regular MVPA moderates the effect of positive and negative affect on MVPA in the following way: Perceiving a strong habit to exercise regularly should strengthen the effect of positive affective states and should buffer the effect of a negative mood.

MATERIALS AND METHODS

This ambulatory assessment study was conducted as a part of the multidisciplinary project *EATMOTIVE* funded by the German Federal Ministry of Education and Research. The participants answered questions regarding their physical activity, sedentary behavior, nutrition, mood, daily hassles and conflicts, and family life on a day level using electronic diaries. Additionally, all participants wore an accelerometer to objectively measure their daily physical activity.

Procedure

We focused on employed adults aged 25–65 years living in the region of Konstanz, Germany. Participants were recruited by initial contact through the "Konstanz Life Study" (Renner et al., 2012) and at two local sport events (games of the regional handball and basketball teams) by the study staff. Eligible participants received verbal information and an information flyer. By writing down their email addresses they agreed to receive an email from the study staff. In addition, university employees received an email with the study information and the option of replying to the email when interested. Interested persons were invited to participate in one of 15 introductory events held every 3 weeks at the University of Konstanz informing participants about the content and the goals of the study. Participants received a smartphone and an accelerometer, learned how to handle the devices and received a paper-pencil questionnaire. Written informed consent was obtained from all participants.

Ethics Statement

The study protocol was defined by a multidisciplinary expert panel of scientists involved in the EATMOTIVE project. The study fully conformed to the Declaration of Helsinki and the ethics guidelines of the German Psychological Society and was approved by the ethics committee of the University of Konstanz. Participants received detailed information regarding voluntary participation, completing questionnaires, and processing of their data according to the ethics guidelines of the German Psychological Society (Deutsche Gesellschaft für Psychologie)[1].

Study Protocol

On the day prior to the diary period all participants were informed on the study and the measuring devices and completed a paper-pencil questionnaire assessing time-invariant variables such as demographics and habit strength.

Each participant received a smartphone (Samsung GT-I9001) to answer daily questionnaires assessing time-variant variables (e.g., positive and negative affect; MVPA) and an ActiGraph GT3X+ accelerometer (ActiGraph, Pensacola, USA) for assessing physical activity. Each participant was tracked for 7 consecutive days starting on a Wednesday. To measure affect, participants received a short text message including a link to an online questionnaire at fixed times during the day: in the morning (t1, prompted at 6:30 a.m.) to be completed after getting up, in the afternoon (t2, prompted 4:30 p.m.) after finishing work, and in the evening (t3, prompted at 9:00 p.m.) to be completed before going to bed. On weekend days, the morning questionnaire was prompted at 8:00 a.m., and no afternoon questionnaire was prompted. Overall, each participants had to answer 19 daily questionnaires (7 mornings, 5 afternoons, and 7 evenings), but only the 5 work days were used for analyses. Ninety-one persons participated in this study. The participant compliance during the 7 days of the study was high with 97.7% completed questionnaires and 79 participants (85.8%) providing complete data on all days.

Measures

Affect

Despite the advantages of electronic diaries for studying psychological processes and their variability in daily life, these methods are demanding for participants. Hence, these questionnaires should be as short as possible to reduce participants' burden and achieve good compliance (Cranford et al., 2006). As we were interested whether positive and negative affective states predict subsequent MVPA differently, we used an

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instrument that allows to measure several discrete affects (Gray and Watson, 2007). Therefore, in line with previous studies we used a categorical measure of distinct affective states, the Profile of Mood States-15 (POMS-15; Cranford et al., 2006). We used a German translation of the two subscales, "vigor" and "fatigue," that represent positive and negative affective states after work (t2). Positive affect represents the experience of a positive mood and negative affect reflects experiencing a negative or aversive mood (Watson and Clark, 1997). Both scales comprise three items (vigor representing a positive affective state: vigorous, cheerful, lively; fatigue representing a negative affective state: fatigued, worn out, exhausted) rated on a 5-point scale ranging from *1—not at all* to *5—extremely*. We only used affect at t2 to examine the influence on subsequent physical activity. Both 3-item scales showed good internal consistencies on all 5 days (positive affect: $\alpha_{\text{day 2}} = 0.83$ to $\alpha_{\text{day 4}} = 0.88$; negative affect: $\alpha_{\text{day 3}} = 0.83$ to $\alpha_{\text{day 5}} = 0.91$).

Physical Activity

Objectively measured moderate to vigorous physical activity

Physical activity was objectively measured using ActiGraph GT3X+ accelerometers (50 Hz, 60 s intervals). Participants were asked to wear the accelerometer on their right hip during waking hours except for water-related activities, such as swimming, bathing, or taking a shower (Swartz et al., 2000; Cain and Geremia, 2012). The average ActiGraph wear time was 14.9 h per day (ranging from 10.1 to 19.2 h), and all participants were included in the analysis (Ward et al., 2005; Cain and Geremia, 2012). Time spent in MVPA (minutes) were calculated as outcome variable based on 60 s intervals of aggregated counts with the software ActiLife (version 6.10.4). Choi's wear time criteria were used to validate wear time (Choi et al., 2011). To optimize data fidelity to our research question, person-specific daily filters were developed to extract physical activity data. The filters were based on the time points t2 and t3 when questionnaires were completed on weekdays. This time frame represents time after work. End times (t3) exceeding midnight, were replaced by 11:59 p.m. Because wear time after work varied between participants, we applied an additional 70/80 wear time validation for the extracted physical activity data (Catellier et al., 2005). Minimal wear time after work was defined as 262 min. Troiano's cut points were used to classify physical activity levels, thus ≥2020 counts-per-minute (CPM) indicated MVPA (Troiano et al., 2008).

Self-reported moderate to vigorous physical activity

Self-reported MVPA was operationalized via time spent with exercising and doing sports. This measure did not cover lifestyle activities such as active commuting. Every evening (t3), participants were asked to answer three questions regarding their MPVA during after work time on the smartphone. They reported how many minutes they had spent in MVPA ["How many minutes did you spent today exercising and doing sports? Please refer to those activities that raised your breathing rate and your heart rate and that made you sweat, e.g., exercising in the fitness studio, jogging, playing tennis, nordic-walking (but not light walking)"], the type of activity, and with whom they performed the activity.

Habit Strength

The medium-term time-invariant variable habit strength was assessed at the beginning of the diary period using the German version (Thurn et al., 2014) of the Self-Report Habit Index (SRHI; Verplanken and Orbell, 2003). The SRHI is a frequently used scale for measuring habit strength by focusing on automaticity of the behavior (Gardner et al., 2011; Gardner, 2014). The stem "Behavior X is something…" (in this case: "Exercising is something…" is followed by 12 items (e.g., "…that I do without thinking"). The items were rated on a 4-point scale ranging from *0—"not true"* to *3—"true."* The mean of the items represents habit strength with high scores indicating a strong habit. The items showed a good internal consistency in this study ($\alpha = 0.94$).

Data Analysis

Multilevel regression models were used to analyze whether affect (day level) and habit strength (person level) predicted the objective after-work MVPA (outcome 1) and self-reported after work MVPA (outcome 2) using the Hierarchical Linear Modeling (HLM) Software version 7.01 (SSI, Inc., IL, USA). In addition, cross-level interactions (habit strength × positive/negative affect) were calculated to analyze whether habit strength had an impact on the influence of positive/negative affect on physical activity. Analyses were performed using random intercept models. Age and gender were included as covariates (person level). Day level variables were centered to the group mean and person level variables were included without centering. All variables were z-standardized to report standardized regression coefficients. For both physical activity outcome variables (objective and self-reported MVPA), separate models for positive and negative affect were calculated. This approach was chosen because of multi-collinearity as positive and negative affect were significantly correlated. Therefore, four models were calculated: positive affect and habit strength as predictors of objective MVPA (outcome 1, Model 1.1); negative affect and habit strength as predictors of objective MVPA (Model 1.2); positive affect and habit strength as predictors of self-reported MVPA (outcome 2, Model 2.1); negative affect and habit strength as predictors of self-reported MVPA (Model 2.2). These models were built up successively. The first step (M0) represents the zero-model to calculate the Intra-Class-Coefficient (ICC). In the second step (M1) the covariates (age and gender) were added to calculate the effects of the covariates. In the third step (M2) the day level variable affect was added. In the fourth step (M3) habit on the person level was added. In the last step (M4) the cross-level interaction was added.

RESULTS

Data of 30 men with a mean age of 43.8 years ($SD = 10.8$ years) and 59 women with a mean age of 45.2 years ($SD = 8.1$ years) were included in the analyses. Thirty-nine participants were full time and 44 were half time employed, one participant was on parental leave and four participants were homemakers.

Fifty-six (62.6%) participants had a university-entrance diploma ("Abitur") and six (6.6%) had an advanced technical college certificate ("Fachhochschulreife"). Seventy-four (83.1%) participants lived in a joint household with their spouse and 71 (79.8%) participants had at least one child living in the household.

Descriptive Results

On average, participants reported 31.2 min of MVPA ($SD = 42.1$ min, ICC = 0.22) during workdays. Eighty-five participants with 236 valid days of after work physical activity data were included in the analyses of objective after work MVPA. The average daily after work wear time was 353.9 min ($SD =$ 79.1 min). On average, participants spent 4.9% ($SD = 6.1\%$) of their after work time in MVPA representing 17.4 min per day ($SD = 21.2$ min). The portion of after work time spent in light physical activity was 33.1% (118 min), whereas 62.0% (218 min) of after work time was spent in sedentary activities. Self-reported and objective after work MVPA were only moderately correlated ($r = 0.32$, $p < 0.001$). The average reported positive affect was $M = 3.49$ ($SD = 0.76$, ICC = 0.38) and the average negative affect was $M = 2.23$ ($SD = 0.87$, ICC = 0.29). The ICC's showed that 62% (positive affect) up to 78% (self-reported MVPA) of the variance was caused by within-person variability. Habit strength was assessed at the beginning of the diary period. Participants reported a habit strength of regularly exercising of $M = 1.83$ ($SD = 0.72$).

Prediction of Objectively Measured after Work MVPA

The person level covariate age was positively related to objective after work MVPA ($\beta = 0.18$, $p < 0.05$; **Table 1**, M1). There was no association between gender and objective after work MVPA ($\beta = -0.06$, $p = 0.46$).

Positive affect, operationalized via three items representing vigor, significantly predicted objective after work MVPA ($\beta = 0.23$, $p < 0.05$; **Table 1**, M2). Higher positive affect in the afternoon was associated with more time subsequently spent in MVPA. There was a main effect of the time-invariant variable habit strength ($\beta = 0.23$, $p < 0.01$; **Table 1**, M3). Strong habits reported before the diary period were associated with higher levels of MVPA during the subsequent workdays. Moreover, there was a significant cross-level interaction effect ($\beta = 0.21$, $p < 0.05$) of positive affect (day level) and habit strength (person level; **Table 1**, M4). The effect of positive affect on after work MVPA differed depending on habit strength and was stronger in combination with a strong habit.

Subjective fatigue, representing a negative affective state, was negatively associated with time in after work MVPA ($\beta = -0.20$, $p < 0.05$), and the higher the negative affect the less MVPA was performed subsequently (**Table 2**, M2). Adding habit strength to the regression model revealed a significant main effect of habit strength ($\beta = 0.23$, $p < 0.01$; **Table 2**, M3). There was a significant cross-level interaction between habit strength and negative affect ($\beta = -0.14$, $p < 0.05$), and the association of negative affect and after work MVPA was influenced by habit strength (**Table 2**, M4). Contrary to our assumptions, habit strength seemed to strengthen the effect of negative affect.

Adding the cross-level interactions (M4) tended to increase the main effects of both positive ($\beta = 0.26$, $p < 0.01$) and negative affect ($\beta = -0.24$, $p < 0.01$) on objective after work MVPA (**Tables 1, 2**, M4).

Prediction of Self-Reported after Work MVPA

Neither age ($\beta = 0.10$, $p = 0.16$) nor gender ($\beta = -0.05$, $p = 0.45$) were significantly related to self-reported after work MVPA (**Tables 3, 4**, M1). The models revealed significant effects of positive ($\beta = 0.18$, $p < 0.01$) and negative affect ($\beta = -0.13$, $p < 0.05$; **Tables 3, 4**, M2) and habit strength ($\beta = 0.28$, $p < 0.001$) on after work MVPA (**Tables 3, 4**, M3). The cross-level interactions were not significant neither for positive ($\beta = 0.01$, $p = 0.89$) nor for negative affect ($\beta = -0.01$, $p = 0.85$; **Tables 3, 4**, M4).

DISCUSSION

The aim of our study was to examine the effect of positive and negative affect on subsequent MVPA. In the last decade, the relationship between physical activity and affect received increasing attention, and there are two perspectives. First, it is assumed that exercising causes affective responses and these affective responses influence exercise adherence (Ekkekakis and Lind, 2006). While there is evidence for the benefits of physical activity on subsequent affective states (Kanning et al., 2013; Liao et al., 2015) only few studies have examined the link between affect and future subsequent physical activity (Williams, 2008).

Secondly, considering the important role of affects in regulating behavior (Russell, 2003; Baumeister et al., 2007) and the importance of behavior regulation in daily life, it seems obvious to assume that affective states impact subsequent physical activity. However, to date the pathway of the relationship between physical activity and affect has not been thoroughly investigated (Schwerdtfeger et al., 2010; Liao et al., 2015).

Affect and Subsequent MVPA

Consistent with preliminary evidence from other studies, we found that a positive affective state (operationalized as the feeling of vigor) in the afternoon was related to more time spent in MVPA in the subsequent hours. In agreement with our results, Dunton et al. (2009) showed that positive affect (operationalized via the rating of the adjective "happy") was associated with higher levels of MVPA in the subsequent interval. Mata et al. (2012) explored the change in affect before engaging in physical activities and found that positive affect (operationalized via the rating of the adjectives "happy," "excited," "alert," and "active") increased over time before engaging in physical activities. However, this observation could originate from positive affect leading to engagement in physical activities or anticipating physical activity leading to increased positive affect. Carels et al. (2007) investigated a longer interval covering the entire day after affect assessment in the morning and showed that a positive affective state (measured via an one-item

TABLE 1 | Model 1.1: Prediction of objective after work MVPA by positive affect and habit strength.

Day level	M0	M1			M2			M3			M4		
	ICC = 0.238	Beta	*SE*	*p*	Beta	*SE*	*p*	Beta	*SE*	*p*	Beta	*SE*	*p*
Intercept		−0.025	0.078	0.748	−0.026	0.078	0.741	−0.012	0.074	0.870	−0.013	0.073	0.859
posA_t2					**0.231**	0.096	0.018	**0.231**	0.096	0.018	**0.264**	0.096	0.007
PERSON LEVEL													
habit								**0.230**	0.072	0.002	**0.230**	0.072	0.002
age		**0.182**	0.079	0.023	**0.182**	0.079	0.023	**0.179**	0.074	0.018	**0.179**	0.074	0.018
gender		−0.059	0.080	0.459	−0.059	0.079	0.461	−0.101	0.076	0.189	−0.100	0.076	0.190
INTERACTION													
habit x posA_t2											**0.205**	0.082	0.013
Deviance	654.43			655.23			654.26			646.23			645.01

Dependent variable: objective MVPA; posA_t2: positive affect measured at t2; habit: habit strength; covariates: age, gender; significant beta coefficients are indicated by bold numbers.

TABLE 2 | Model 1.2: Prediction of objective after work MVPA by negative affect and habit strength.

Day level	M0	M1			M2			M3			M4		
	ICC = 0.238	Beta	*SE*	*p*	Beta	*SE*	*p*	Beta	*SE*	*p*	Beta	*SE*	*p*
Intercept		−0.025	0.078	0.748	−0.003	0.078	0.741	−0.012	0.074	0.870	−0.013	0.073	0.864
negA_t2					**−0.203**	0.085	0.017	**−0.203**	0.084	0.017	**−0.244**	0.086	0.005
PERSON LEVEL													
habit								**0.230**	0.072	0.002	**0.230**	0.071	0.002
age		**0.182**	0.079	0.023	**0.182**	0.079	0.023	**0.179**	0.074	0.018	**0.179**	0.074	0.018
gender		−0.059	0.080	0.459	−0.059	0.079	0.461	−0.101	0.076	0.189	−0.101	0.076	0.189
INTERACTION													
habit x negA_t2											**−0.136**	0.069	0.048
Deviance	654.43			655.23			654.45			646.42			647.85

Dependent variable: objective MVPA; negA_t2: negative affect measured at t2; habit: habit strength; covariates: age, gender; significant beta coefficients are indicated by bold numbers.

one-dimensional emotion scale) in the morning was related to the initiation of exercise during the day in obese adults, but not to its duration and intensity. However, it should be recognized that Dunton et al. (2009), Mata et al. (2012), and Carels et al. (2007) used self-report measures for both affective states and physical activity. Dunton et al. (2014) used accelerometers to measure MVPA and found that "feeling energetic" was associated with more time in MVPA in the subsequent 30 min in children. Schwerdtfeger et al. (2010) also used accelerometers and found that positive affect (operationalized via the rating of the adjectives "lively," "awake," "active," "powerful," "dynamic," and "happy") was significantly associated with higher levels of MVPA in four intervals: 1, 5, 15, and 30 min after affect measurement. In contrast to Schwerdtfeger et al. (2010) and Dunton et al. (2014), we considered a longer interval covering the time between answering the t2 questionnaire and going to bed. On average, this interval covered almost 6 h. Therefore, affect seems to influence subsequent short to medium term physical activity and this influence remains significant even when considering a longer interval of more than 5 h. Our study provides additional evidence regarding the role of positive affect in the regulation of physical activity behavior.

The results on negative affect were less consistent. In our study higher negative affect, operationalized via subjective fatigue, was associated with lower levels of subsequent MVPA. This result is consistent with the result of Dunton et al. (2009) (negative affect: "emotionally upset," "stressed," "lonely/alone," "annoyed/angry," "tense/anxious," "sad/depressed," and "discouraged/frustrated") and Dunton et al. (2014) (emotional state: "feeling tired") but in contrast to Schwerdtfeger et al. (2010) ("nervous," "stressed," "irritable," "depressed," "relaxed" '[-]), who reported increase in physical activity in the medium intervals (15 and 30 min) after assessment of negative affect. Mata et al. (2012) found no association between negative affect ("anxious," "sad," "disgusted," "angry," "guilty," "ashamed," "frustrated") and subsequent physical activity. Hence, further research in this field in general is warranted, and especially the role of negative affect should be investigated in future studies.

Participants in our study overestimated their levels of MVPA by 45%. Nonetheless, we observed the same pattern of associations for objective and self-reported MVPA. However, the association between positive and negative affect and self-reported after work MVPA was weaker than that of objective after work MVPA. These slightly different results for objective

TABLE 3 | Model 2.1: Prediction of self-reported after work MVPA by positive affect and habit strength.

Day level	M0	M1			M2			M3			M4		
	ICC = 0.223	Beta	*SE*	*p*	Beta	*SE*	*p*	Beta	*SE*	*p*	Beta	*SE*	*p*
Intercept		−0.011	0.067	0.869	−0.003	0.068	0.969	−0.02	0.061	0.970	−0.002	0.060	0.969
posA_t2					**0.176**	0.058	0.002	**0.176**	0.058	0.002	**0.177**	0.070	0.012
PERSON LEVEL													
habit								**0.282**	0.062	<0.001	**0.282**	0.059	<0.001
age		0.096	0.067	0.155	0.084	0.068	0.223	0.082	0.062	0.187	0.082	0.077	0.290
gender		−0.051	0.067	0.446	−0.055	0.068	0.424	−0.098	0.062	0.117	−0.098	0.068	0.154
INTERACTION													
habit x posA_t2											0.009	0.064	0.890
Deviance	1219.23		1223.98			1205.31			1188.48				1194.10

Dependent variable: self-reported MVPA; posA_t2: positive affect measured at t2; habit: habit strength; covariates: age, gender; significant beta coefficients are indicated by bold numbers.

TABLE 4 | Model 2.2: Prediction of self-reported after work MVPA by negative affect and habit strength.

Day level	M0	M1			M2			M3			M4		
	ICC = 0.223	Beta	*SE*	*p*	Beta	*SE*	*p*	Beta	*SE*	*p*	Beta	*SE*	*p*
Intercept		−0.011	0.067	0.869	−0.003	0.068	0.969	−0.002	0.061	0.970	−0.002	0.061	0.970
negA_t2					**−0.132**	0.055	0.017	**−0.132**	0.055	0.017	**−0.132**	0.055	0.017
PERSON LEVEL													
habit								**0.282**	0.062	<0.001	**0.282**	0.062	<0.001
age		0.096	0.067	0.155	0.084	0.068	0.223	0.082	0.062	0.187	**0.082**	0.062	0.187
gender		−0.051	0.067	0.446	−0.055	0.068	0.424	−0.098	0.062	0.117	**−0.098**	0.062	0.117
INTERACTION													
habit x negA_t2											−0.010	0.051	0.845
Deviance	1219.23		1223.98			1208.89			1192.06				1197.97

Dependent variable: value self-reported MVPA; negA_t2: negative affect measured at t2; habit: habit strength; covariates: age, gender; significant beta coefficients are indicated by bold numbers.

and self-reported MVPA indicate that the link between affect and physical activity must be examined with a differentiated view on physical activity. Accelerometer and self-reported data reflect different facets of physical activity: while accelerometer data covers all bodily movements, self-reported physical activities refer to physical exercise and sports that are done mostly intentionally. Further studies should focus on different types of activity and on subsequent physical activity in different intervals.

Interestingly, the measurement of affect differed considerably among previous studies (Carels et al., 2007; Dunton et al., 2009, 2014; Schwerdtfeger et al., 2010; Mata et al., 2012) possibly explaining some of the inconsistencies in the results. For instance, Dunton et al. (2014) assessed positive affect via the adjectives "happy" and "joyful" and negative via the adjectives "stressed," "mad or angry," "nervous or anxious," and "sad" (rated on a 4-point scale ranging from "not at all" to "extremely") and found no associations with MVPA, whereas "physical feeling states," operationalized via two items ("feeling tired" and "feeling energetic," rated on the same 4-point scale) were significantly associated with subsequent MVPA. Feeling energetic was associated with higher levels of MVPA and feeling tired predicted lower levels of physical activity. In our study, negative affective state was operationalized via the feeling of fatigue measured with four items, and we found a negative association with physical activity. Whereas Schwerdtfeger et al. (2010) used the adjectives "nervous," "stressed," "irritable," "depressed," "relaxed(-)" and found an inverse relationship (negative affect predicted higher levels of physical activity). Mata et al. (2012) used the adjectives "anxious," "sad," "disgusted," "angry," "guilty," "ashamed," and "frustrated" and found no association. Moreover, it should be noted that different terms were used for equal constructs (for example mood, affect, affective states, feeling states). It is possible that the findings regarding the link between affect and physical activity differ depending on the facet of positive/negative affect that is measured, and maybe adjectives such as "happy" or "sad" are too general to be related to subsequent physical activity. Therefore, further studies should examine different facets of positive and negative affect and their association with subsequent MVPA.

Finally, previous studies have included different populations, and hence the observed inconsistencies may also be caused by population specific characteristics. Moreover, inter-individual differences in the link between affect and physical activity may be present because of individual characteristics.

The Role of Habit Strength

To the best of our knowledge, the role of time-invariant variables such as habit strength has not been investigated in relation to the affect-physical activity link. Habits are beneficial (although some may be disadvantageous, too) for regulating behavior in daily life because they require little cognitive effort and are efficient (Wood et al., 2002). Habitual behavior is less vulnerable to disturbances than deliberative behavior, and the stronger the habit to be physically active the more the persons are physically active (Gardner et al., 2011). As hypothesized we found that habit strength predicted after work MVPA throughout the week. In addition and in line with our assumption, there was a cross-level interaction effect for both positive and negative affect indicating that habit strength has an impact on the relationship between affect and behavior. However, in contrast to our hypothesis, the direction of this cross-level interaction indicated that a strong habit of being physically active strengthened the influence of negative affect. Negative affect reduced subsequent MVPA more in combination with a strong habit. It is possible that the previously mentioned benefit of cognitive efficacy and unconsciousness of habitual behavior turns into a disadvantage if self-control processes are not activated. Accordingly, we did not find a cross-level interaction effect for self-reported MVPA and the effect sizes of affect tended to be smaller. Self-reported MVPA mainly reflects intentional or planned physical activities representing the reflective pathway to action, and this pathway is characterized by conscious regulation processes. Negative affect seems to have a detrimental influence even on these physical activities but this effect was slightly smaller and was not strengthened in combination with a strong habit. Habit strength seems not to be relevant for the association between these activities and negative affect. Examining the role of intentions or self-regulatory processes in this context would be interesting. Moreover, studies on inter-individual differences in the link between affect and physical activity should integrate other person level variables, such as intrinsic vs. extrinsic motivation or goal orientation.

Strength and Limitations

A major strength of this study was the ambulatory assessment design allowing investigating the relationship between affect and physical activity between and within persons in daily life. We combined continuous accelerometer-monitoring of physical activity with electronic diary assessment of the momentary affective state. In addition, physical activity was measured subjectively via daily self-reports. Thus, the study design fully complies with the recommendations of Kanning et al. (2013) regarding the methodological requirements necessary for investigating within-subject associations between affective states and physical activity in daily life.

The fact that the sample was better educated than the average German population (Statistisches Bundesamt[2]) is a limitation of this study possibly limiting the generalizability of the findings. Moreover, 5 weekdays may not be a sufficient representation of usual behavior in daily life. However, longer electronic diary periods increase participants' burden and likely reduce compliance. We restricted affect measurement to eight items—four items for positive affect and four items for negative affect—to reduce participants' burden. Finally, although there appears to be a causal relationship between affect and subsequent MVPA, it is possible that other variables may influence both affect and physical activity in a similar way.

CONCLUSION

In this study, we used ambulatory assessment to examine the relationship between affect and physical activity in a real-life setting. Positive affect increased and negative affect decreased objective and self-reported MVPA. Hence, affective states play an important role in the regulation of physical activity in daily life. Although more research is needed to confirm these findings, our results and those of few other studies indicate that considering unconscious processes, e.g., triggered via affects, might improve the explanation and prediction of engagement and especially maintenance of physical activity in daily life. Furthermore, adapting intervention strategies such as planning by considering the role of affects for daily behavior regulation, might improve long-term behavior change.

In addition, we found that the relationship between affect and physical activity is influenced by habit strength where the stronger the habit of being physically active the stronger the effect of positive but also of negative affect. Future studies should integrate time-invariant variables such as motives or goal orientations to gain further insight into the complexity of the relationship between affect and physical activity.

AUTHOR CONTRIBUTIONS

CN was responsible for the overall conception, design and analysis of this study and wrote the manuscript. CH conducted the statistical analyses, contributed to the interpretation of the study results and revised the manuscript. BV and DV contributed to the conception of the manuscript, writing the manuscript, were responsible for preparing the accelerometer and electronic diary data for statistical analysis, the data management, and revised the manuscript. AW participated in the conception and design of the study. All authors read and approved the final manuscript.

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[2]https://www.destatis.de/DE/ZahlenFakten/GesellschaftStaat/BildungForschungKultur/Bildungsstand/Tabellen/Bildungsabschluss.html

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The Bidirectional Effect between Momentary Affective States and Exercise Duration on a Day Level

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Despite the well-documented positive effect of exercise on health outcomes, most people do not succeed in exercising regularly. In addition to several other influences, affective states seem to support exercise participation. Associations between exercise and affect have been shown in the laboratory. However, the dynamic relation between affect and exercise in daily life is not yet well-understood. The objective of this study was to investigate the bi-directional effect of momentary affective states on naturally occurring exercise and vice versa in healthy participants in real-life environments by applying an ecological momentary assessment design. We hypothesized that (1) exercise duration is positively associated with affective states on a day level, (2) affective states in the morning predict subsequent exercise duration, and (3) exercise duration predicts affective states in the evening on that respective day. Data from $N = 60$ students aged between 19 and 32 years were analyzed. Affect and exercise duration were assessed daily over a period of 20 days via an electronic diary. Multilevel analysis revealed that positive affective valence was positively associated with exercise duration ($p = 0.003$) on a day level. In addition, the more the participants exercised that respective day, the better and more content they felt in the evening ($p = 0.009$). Energetic arousal in the morning significantly predicted subsequent exercise duration ($p = 0.045$). The findings indicate that it would be worthwhile to focus more on within-subject analyses when analyzing the dynamic relation between affect and exercise. Furthermore, affective states should be taken into account in creating effective interventions to foster exercise behavior and enhance maintenance.

Keywords: ambulatory assessment, ecological momentary assessment, mood, physical activity, health behavior

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INTRODUCTION

Most people do not reach the recommended volume of exercise, even though the health-enhancing effects are well-documented (Lee et al., 2012). Many factors have been examined as influencing factors on exercise behavior (Fuchs et al., 2012). Recent research has focused on state variables such as affect (Jekauc, 2015). An understanding of the dynamic relation between affective states and exercise may help to create effective exercise promotion programs. Ample evidence shows positive associations between positive affective states and exercise (Berger and Motl, 2000). However, most previous studies have investigated this association in the laboratory (Liao et al., 2015), whereas studies about the association between affective states and physical activity are rare, and findings are contradictory (Kanning et al., 2013; Liao et al., 2015). In addition, in attempting to understand the dynamic relation between these two variables, researchers have seldom focused on within-subject analyses, which have the advantage of yielding knowledge about dynamic processes rather than just about between-person differences. This study uses an ambulatory assessment approach to analyze the bi-directional effect between affective states and physical activity, especially naturally occurring exercise, in real life in healthy participants.

The effect of physical activity or exercise on affect has often been shown in the laboratory, which allows a controlled design (Ekkekakis and Petruzzello, 2000). However, these studies lack external validity. A few recent field studies have tried to answer the question of whether affective reactions are associated with physical activities in real life (e.g., Dunton et al., 2009, 2014; Schwerdtfeger et al., 2010; Kanning et al., 2013; von Haaren et al., 2013). The authors of these studies chose ecological momentary assessment (EMA) as a suitable method to collect real-time data in daily life (Shiffman et al., 2008). EMA involves having test subjects wear a tool in daily life that beeps and prompts them to complete an electronic diary on their phone.

In a review, Liao et al. (2015) systematically examined the short-term associations between affective states and subsequent acute free-living physical activity as well as the short-term associations between physical activity and subsequent affective states. Most of the EMA studies included in the review that examined the association between affect and subsequent physical activity found a positive association between positive affective valence and physical activity, whereas evidence of negative affective valence predicting physical activity was inconclusive. A study by Dunton et al. (2014) succeeded in additionally showing that energetic arousal positively predicts physical activity in children. Some studies examined in the review of Liao et al. (2015) also found an increase in energetic arousal and a decrease or an increase in calmness following physical activity. The mixed results of the association between physical activity and calmness might be explained by the length of the time interval between the assessment of both variables. When measuring calmess within 1 h after physical activity, a decrease in calmness has been shown (Kanning, 2013; Kanning et al., 2015). With longer time intervals an increase in calmness can be detected (Gauvin et al., 1996).

In conclusion, evidence suggests that positive affective valence and energetic arousal predict subsequent physical activity and that physical activity leads to positive affective valence and may affect calmness. However, most of the studies examined in the review by Liao et al. (2015) defined physical activity as activity in daily life, not solely activity executed for the purpose of exercising. Carels et al. (2007), for example, investigated the association between affect and exercise and found that affect in the morning is associated with an increased likelihood to exercise that day in obese dieters. They also found that positive affective valence following exercise is higher when the duration and intensity of the exercise are higher.

As demonstrated above, there is reason to assume that there is an association between affective states and exercise in real life. Understanding this association may be important for creating effective exercise promotion programs. Positive experiences with exercising might positively affect long-term maintenance ("outcome experiences"; Fuchs et al., 2012). A recent study by Jekauc (2015) has shown that inducing positive affect during exercise has an effect on long-term maintenance, indicating that positive affective valence plays an important role in exercise behavior prediction. Affecting attitudes through affective messages has been shown to lead to a stronger increase in exercise participation than affecting attitudes through health-related messages (Conner et al., 2011). In sum, positive affective valence can, if associated with exercising, be considered one of the strongest factors contributing to the maintenance of exercise behavior.

Empirical results indicate that there is an association between affect and physical activity in real life. We would like to broaden the evidence by testing whether there is also a bi-directional association between momentary affective states and freely occurring daily exercise participation in healthy participants. Unlike previous studies investigating daily life activities such as stairway climbing or vacuuming, our study aims to gain insights into planned sport activities (encompassing either classical "sports" or health-related physical exercise). We are interested in whether naturally occurring sport and exercise behavior is related to affective states. To avoid retrospective distortions and to observe real-life effects, we collected our data using electronic diaries (EMA). Our primary research hypothesis, developed on the basis of previous findings, was that (1) a participant would exercise more on days on which he or she reported higher mean positive affective valence, higher mean energetic arousal, and higher mean calmness. With regard to an additional focus on the temporal relationship between affect and naturally occurring exercise, we assumed in our second hypothesis that (2) high positive affective valence, high energetic arousal, and high calmness in the morning would predict longer exercise duration on that day. In our third hypothesis, we expected that (3) the more the participant exercised that day, the higher would be the positive affective valence, energetic arousal, and calmness reported by that participant in the evening.

MATERIALS AND METHODS

Participants

Out of 75 participants, $N = 60$ participants provided sufficient data to be included in the analysis. We excluded 15 participants because they did not engage in any exercise during the 4 weeks of data collection or more than 50% of their values were missing or their data could not be analyzed due to technical problems. The sample included participants aged between 19 and 32 years ($M = 23.5$; $SD = 2.8$); 20 were male and 40 female. Data was collected in three waves: April 2015 (Wave 1), May and June 2015 (Wave 2), and July and August 2015 (Wave 3). Participants were recruited via leaflets and posters distributed in different buildings of the University of Freiburg. Potential participants were invited to write us an e-mail so that we could call them back and screen them for eligibility. Individuals were included if they currently exercised at least once a week for at least 30 min. In addition, since we intended to investigate activities that are self-directed and therefore might be affected by momentary states, participants had to indicate that they did not exercise solely because they felt obliged to do so because of other people (athletic clubs, parents, friends). Individuals who were competitive athletes or were enrolled in a sports science degree program or had undergone psychiatric therapy/treatment in the previous 12 months were excluded from the study. Individuals who met the eligibility criteria were scheduled for the initial laboratory meeting at the university. Participants received a financial compensation of 20 € after the end of the study.

Procedure

The study protocol was reviewed and approved by the institutional ethics committee. For data collection, we used an electronic diary via smartphones ("Google Nexus 5": LG, Seoul, South Korea), using the app "movisensXS" (movisens GmbH, Karlsruhe, Germany). We chose to collect data over a long period (20 working days) in order to obtain generalizable data. In addition, we assumed that methododological reactivity, the possibility that participants change their usual beahvior because it is being monitored, would be less likely if the data collection period was longer. At the initial laboratory meeting, participants gave their written consent, completed a questionnaire assessing demographic characteristics, received the necessary equipment, and were instructed on how to operate the smartphones. They were also informed about the following facts and procedures during the study period of 20 working days (Monday to Friday): the calling and Internet capabilities of the smartphones were disabled. The participants were asked to keep the phones switched on throughout the period. An acoustic signal prompted the participants to make an entry of data collection in the electronic diary at four random measurement points per day within four pre-programmed time windows: in the morning (between 9:30 and 10:30 a.m.), around midday (between 12:30 and 1:30 p.m.), in the evening (between 4:30 and 5:30 p.m.), and at bedtime (between 10:00 and 11:00 p.m.). If the participant made no entry, the smartphone beeped again after a few minutes. The participants could also decline to make entries or delay them by up to 20 min. During class or in the library, the students could set the phones to a vibration mode. The app was programmed to display the questions and provide the response choices on the smartphone screen. The completion of the electronic diary entry took about 2–3 min. Affect scores were assessed at all measurement points, four times a day for 20 working days. At bedtime, participants additionally provided data on the amount of time they had spent exercising that day. After the data collection period, participants were invited to the laboratory again to return the smartphones and to receive the financial compensation. Data were stored on the phone and were downloaded to a server after the end of the study.

Measures of Affect

There are many different definitions and specifications of mood, emotions, and affect. In the current paper, we follow Panteleimon Ekkekakis's definition of affect as an "immediate, uncontrollable, automatic response" (p. 95), a "pleasant or unpleasant feeling that does not require any prior cognitive processing" (p. 95), with typical affects being the feeling of "pleasure vs. displeasure," "energy vs. tiredness," or "tension vs. calmness" (Hanin and Ekkekakis, 2014, p. 95). To assess the variability of affect in daily life, we used a short scale for assessing affect developed and validated for EMA by Wilhelm and Schoebi (2007) and based on the Multidimensional Mood Scale (MDMQ; Steyer et al., 1997). The six-item scale measures three dimensions of affect with two bipolar items per dimension: valence (well–unwell; content–discontent), energetic arousal (tired–awake; full of energy–without energy), and calmness (agitated–calm; relaxed–tense). Participants had to rate the items on a seven-point scale on the basis of the statement "At the moment, I feel . . ." They provided the answers by choosing a number from 0 to 6 on the display.

Measures of Naturally Occurring Exercise

Naturally occurring exercise was measured as a continuous variable (exercise duration) by the item "How many minutes in total have you been engaging in exercise today?" Participants could type in the number of minutes. At the initial laboratory meeting, participants were explained the difference between instrumental "everyday life activities" (e.g., stair climbing, going to work by bicycle) and activities that are defined as "exercise behavior" (including all classical sports and health-related exercises; Fuchs et al., 2015). Most of the studies mentioned above used accelerometers to assess physical activity objectively. Since we were not interested in daily life physical activity but in naturally occurring planned exercise done for its own sake (sports) or for health-related reasons, which will probably occur only every 2–3 days, it was not necessary or suitable for our participants to wear accelerometers during the entire period of data collection (20 days). This would have placed another burden on the participants, possibly reducing compliance. Therefore, we relied on EMA self-reports to assess naturally occurring exercise duration.

Data Analysis

Since we wished to observe exercise duration as it occurs in real life, the time of the day for exercising will differ from individual to individual and from day to day. In addition, it is hard to assess affect directly before and after episodes of exercise in real life since the event "exercise duration" occurs too infrequently in real life (e.g., three times a week). We therefore decided to assess affect four times a day at fixed time points and used the mean level of all four affect measurements from the whole day to clarify whether there was an association between affect and exercise duration on a day level. Plus, we used the morning affect measurement point to predict exercise duration on that day (Carels et al., 2007) and the evening affect measurement point to predict affective reactions from exercise duration that day.

The data from our study had a nested structure, with 20 days nested within 60 persons. Therefore, we estimated multilevel models using HLM 7.0 (Raudenbush et al., 2011). Multilevel models can differentiate between within-subject effects (level 1: day level) and between-subject effects (level 2: person level). We used restricted maximum likelihood estimations for the analysis and set the α-level of the tests to $p < 0.05$. Prior to analysis, within-person predictors were person-mean centered (Snijders and Bosker, 2011). We started by ckecking if the affect assessment data of the different days were not correlated. If participants reported similar affect scores on two consecutive measurement occasions, there is a risk of underestimation of the within-subject variability (Schwartz and Stone, 1998). Correlations are provided in Supplementary Material.

Model 1: Association between exercise duration and affective states on a day level

In the first analysis, we started by estimating the intra-class coefficient (ICC) in a model in which exercise duration is not modeled as a function of another variable. Second, we entered the predictor variables valence, energetic arousal, and calmness (day mean) into the model on level 1. We also entered gender into the model on level 2 as a control variable.

Level 1 Model:

$$\text{Exercise duration}_{\text{ti}} = b_{0\text{i}} + b_{1\text{i}}{}^{*}(\text{Valence})_{\text{ti}} + b_{2\text{i}}{}^{*}(\text{Energetic arousal})_{\text{ti}} + b_{3\text{i}}{}^{*}(\text{Calmness})_{\text{ti}} + r_{\text{ti}}$$

Level 2 Model:

$$b_{0\text{i}} = \gamma_{00} + \gamma_{0\text{i}}{}^{*}(\text{Gender}) + \mu_{0\text{i}}$$
$$b_{1\text{i}} = \gamma_{0} + \gamma_{11} + \mu_{1\text{i}}$$
$$b_{2\text{i}} = \gamma_{20} + \gamma_{21} + \mu_{2\text{i}}$$
$$b_{3\text{i}} = \gamma_{30} + \gamma_{31} + \mu_{3\text{i}}$$

The level 1 model represents the participant's responses (subscript i) to the exercise duration item on the day level (subscript t). Exercise duration is a function of the intercept b_{0i} and the three level 1 predictors (b_{1i}, b_{2i}, b_{3i}). b_{1i} is the effect of the within-person valence, meaning the increase in exercise duration with every increase of valence. b_{2i} is the within-person effect of energetic arousal, and b_{3i} is the within-person effect of calmness. The error for level 1 is given by r_{ti}. Level 2 expresses the between-subject effect, including the fixed effects γ_{00} of the averaged intercepts and slopes across all participants and the covariate γ_{0i}, which displays the effect of gender on exercise duration. This level also includes the random effect μ_{0i}.

Model 2: Subsequent exercise duration as predicted by affective states

In the second model, we entered the affect variables into the model like in model 1, but instead of using the day mean for each affect dimension, we used only the affect data collected at the morning assessment point.

Model 3: Subsequent affective states as predicted by exercise duration

In the third model, we started again by estimating the ICC but this time in three different models without predictors. Valence, energetic arousal, or calmness functioned as the respective outcome variables in the three models. In a second step we entered exercise duration as a level 1 predictor, and in a third step we entered gender on level 2. On the basis of these variables, we estimated whether valence, energetic arousal, and calmness (intercept) varied significantly as a function of gender.

Level 1 Model:

$$\text{Affect (Valence/Energetic arousal/Calmness)}_{\text{ti}} = b_{0\text{i}} + b_{1\text{i}}{}^{*}(\text{Exercise duration})_{\text{ti}} + r_{\text{ti}}$$

Level 2 Model:

$$b_{0\text{i}} = \gamma_{00} + \gamma_{01}{}^{*}(\text{Gender}) + \mu_{0\text{i}}$$
$$b_{1\text{i}} = \gamma_{10} + \gamma_{11} + \mu_{1\text{i}}$$

The Level 1 model calculated the within-subject effects. It represents the participant's responses (subscript i) on one of the affect subscales on a day level (subscript t). The affect subscale is a function of the individual intercepts b_{0i} and b_{1i}, which is the effect of the within-person exercise duration, meaning the increase in affect with every increase of exercise duration. On Level 2, γ_{01} displays the effect of gender on affect.

RESULTS

Descriptive Analysis

The sample with $N = 60$ participants provided 1072 data points for model 1 (association), 1159 data points for model 2 (exercise duration as predicted by morning affect), and 1082 data points for model 3 (evening affect as predicted by exercise duration). The overall average exercise duration across all subjects per day was $M = 38.7$ min ($SD = 50.9$ min), with a range from 0 to 300 min. Overall, the participants exercised on 48.2% of the days (exercise duration > 0 min), with a range from 2 to 17 days (out of 20 days) per person. The average daily levels for valence, energetic arousal, and calmness were 9.8 ($SD = 1.7$), 8.6 ($SD = 1.7$), and 9.3 ($SD = 1.5$), respectively, representing a medium levels of affective states.

Test of Hypotheses

Model 1: Association between naturally occurring exercise duration and affective states on a day level

To test whether affect is associated with exercise duration on a day level, we first estimated the ICC of exercise duration ($\rho_I = 0.16$). It indicated that 84% of the variability in exercise duration was attributed to within-person differences and only 16% to between-person differences. This demonstrates that exercise duration shows substantial within-person variation on a day level, which requires a multilevel approach. Next, we entered the predictors into the model. The model is presented in **Table 1**. The random effects of the energetic arousal and calmness slope were not significant, so they were removed. The slope of valence varied between persons ($p < 0.001$). Exercise duration was almost significantly associated with gender ($p = 0.050$), indicating that men exercised more than women. We also found that exercise duration was significantly positively associated with valence ($p = 0.003$) but not with energetic arousal ($p = 0.239$), indicating that good feelings were related to a longer exercise duration. The association between exercise duration and calmness was negative but not significant ($p = 0.141$).

Model 2: Subsequent exercise duration as predicted by affective states

In model 2, the three dimensions of affect that were assessed in the morning functioned as predictors of exercise duration that day. The random effects of the three slopes were not significant, so they were removed. The model is presented in **Table 2**. We found that exercise duration was again almost significantly associated with gender ($p = 0.052$) and with energetic arousal ($p = 0.045$) but not with the other affect dimension (valence: $p = 0.736$; calmness: $p = 0.740$).

Model 3: Subsequent affective states as predicted by exercise duration

The last model estimated the extent to which exercise duration predicts affect in the evening. The results for the ICC were $\rho_I = 0.22$ for valence, $\rho_I = 0.23$ for energetic arousal, and $\rho_I = 0.24$ for calmness, indicating that 78, 77, and 76% of the affect subscale's variance, respectively, was caused by within-person variation. The model is presented in **Table 3**. In the valence model, the random effects of exercise duration varied between persons ($p = 0.043$), whereas the random error terms of exercise duration in the other models had to be removed. Valence in the evening was significantly predicted by gender ($p < 0.001$) and by exercise duration ($p = 0.009$), indicating that men felt better and more content in the evening than women and that participants felt better and more content the longer they had exercised that day. Energetic arousal and calmness were both significantly predicted by gender ($p = 0.002$; $p = 0.003$) but not by exercise duration ($p = 0.954$; $p = 0.144$). The random error terms of the slopes in these models were not significant, so they were fixed. Gender differences indicated that men had significantly higher scores on all three affect subscales.

TABLE 1 | Predicting exercise duration by valence, energetic arousal, and calmness on a day level.

	Fixed effects				Random effects			
	Est	*SE* (df)	*t*-ratio	*p*-value	Variance estimate	*SD*	*X*(df)	*p*-value
Intercept	22.88	8.38 (58)	2.73	0.008	443.02	21.05	240.58 (57)	<0.001
Gender	11.77	5.89 (58)	1.99	0.050				
Valence	2.02	0.65 (59)	3.11	0.003	5.23	2.29	105.12 (58)	<0.001
Energetic arousal	0.44	0.37 (666)	1.18	0.239				
Calmness	−0.63	0.43 (666)	−1.48	0.141				

TABLE 2 | Prediction of daily exercise duration by valence, energetic arousal, and calmness in the morning.

	Fixed effects				Random effects			
	Est	*SE* (df)	*t*-ratio	*p*-value	Variance estimate	*SD*	*X*(df)	*p*-value
Intercept	22.59	8.86 (58)	2.55	0.013	406.96	20.17	243.12 (58)	<0.001
Gender	12.15	6.13 (58)	1.98	0.052				
Valence	0.46	1.37 (916)	0.34	0.736				
Energetic arousal	1.55	0.77 (916)	2.01	0.045				
Calmness	−0.34	1.03 (916)	−0.33	0.740				

TABLE 3 | Prediction of valence, energetic arousal, and calmness by exercise duration.

	Fixed effects				Random effect			
	Est	*SE* (df)	*t*-ratio	*p*-value	Variance estimate	*SD*	*X*(df)	*p*-value
Model: valence								
Intercept	8.49	0.41 (58)	20.48	<0.001	0.94	0.97	285.94 (58)	<0.001
Gender	1.13	0.28 (58)	4.08	<0.001				
Exercise duration	0.00	0.00 (59)	2.69	0.009	0.01	0.00	78.78 (59)	0.040
Model: energetic arousal								
Intercept	5.59	0.52 (58)	10.73	<0.001	1.52	1.23	314.93 (58)	<0.001
Gender	1.17	0.35 (58)	3.302	0.002				
Exercise duration	0.00	0.00 (981)	0.06	0.954				
Model: calmness								
Intercept	8.34	0.49 (58)	17.03	<0.001	1.36	1.17	342.82 (58)	<0.001
Gender	1.078	0.34 (58)	3.15	0.003				
Exercise duration	0.01	0.00 (981)	1.46	0.144				

DISCUSSION

This ambulatory assessment study analyzed the bi-directional effects of naturally occurring exercise duration on affective states and vice versa. The within-subject associations revealed three important findings: first, only positive affective valence was positively associated with exercise duration on a day level; second, only energetic arousal in the morning predicted subsequent exercise duration that day; and third, exercise duration only predicted higher positive affective valence in the evening. Thus, our hypotheses were only partly confirmed since we could only find effects on one of the three dimensions (positive affective valence, calmness, energetic arousal) for each analysis. The significant effects of gender in the analyses might be due to the fact that we had an unequal distribution of gender in our sample. The findings support the hypothesis that positive affective valence is positively related to naturally occurring exercise. This is in line with other findings (Gauvin et al., 1996; Carels et al., 2007; Dunton et al., 2009, 2014; Kanning and Schlicht, 2010; Schwerdtfeger et al., 2010; von Haaren et al., 2013). However, our data did not support the hypothesis that the feeling of being energized (energetic arousal) or relaxed (calmness) is related to exercise duration. However, this result is consistent with findings from Dunton et al. (2009), who also did not find a significant positive association between energetic arousal and physical activity among middle-aged and older adults.

To obtain evidence on the temporal sequence and direction of the association between naturally occurring exercise and affect, we investigated whether affect predicted exercise duration in the morning and whether exercise duration predicted affect in the evening. Findings revealed that only energetic arousal in the morning predicted exercise duration. Participants exercised more on days on which they felt energized and awake in the morning. This finding is in line with results from Dunton et al. (2014), who found that an energetic feeling predicts physical activity in children. Contrary to findings from other ambulatory assessment studies (e.g., Schwerdtfeger et al., 2010; Dunton et al., 2014), we did not find that positive affective valence predicts exercise. These studies revealed that positive feelings predict subsequent physical activity. However, Schwerdtfeger et al. (2010) assessed "positive activated affect," measured with six items: lively, awake, active, powerful, dynamic, and happy. It comprises positive affective valence as well as energetic arousal. The results indicate that it might be wise to assess the two dimensions separately.

With regard to our third hypothesis, the data confirmed previously published findings by showing that the more participants exercise, the better and more content they feel (positive affective valence) in the evening of that respective day. This is in line with results from Gauvin et al. (1996), Carels et al. (2007), Mata et al. (2012), von Haaren et al. (2013), and Kanning et al. (2015), who found a positive association between physical activity and subsequent positive affect. In contrast to our findings, some of these studies also reported significant associations between physical activity and energetic arousal as well as physical activity and calmness. However, most former studies analyzed the association between momentary affect and momentary activity in daily life. They did not assess whether physical activity or exercise predict affective states in the evening. It may be that the association between affect and activity depends on the assessment interval. It could be that feelings of relaxation and power will disappear as time goes by. Further studies are needed to assess the predictive power of physical activity and exercise on subsequent affect in different time frames.

Our main results are that participants exercised more on days on which positive affective valence was high and that they showed higher positive affective valence in the evening the more they had exercised that day. Plus, the more energized and awake participants felt in the morning, the more they exercised that day. Our explanation for the positive association between positive affective valence and exercise is that positive affective valence facilitates exercise behavior by motivating the individual. According to Baumeister et al. (2007), affect acts as a short-term, intra-individual predictor of behavior since automatic positive affective valence leads to an increase in goal pursuit. It may be assumed that when individuals experience positive affect, they become motivated to reach their long-term health goals, thus facilitating exercise initiation. Positive affect has also been shown to counteract ego-depletion (Ren et al., 2010), which is a state of a diminished self-control resource (Baumeister, 2002). Ego-depletion follows after a person has carried out tasks that require self-control. In daily life, it may be the case that self-control is low due to daily self-control demands that an individual is confronted with, and as a consequence the individual may no longer be capable of initiating a behavior that requires self-control. Exercise behavior depends on self-control since it is related to long-term health goals. Positive affect might compensate for diminished self-control. Feeling energized in the morning might have the same effect. It may be an indicator of high self-control on that day. In sum, affect may play a role in the acute initiation and duration of exercise, because the current state of the individual is a predictor of current behavior. However, since data analyses have shown that the more participants exercise, the higher their positive affective valence is in the evening, it also seems plausible to assume that the relationship works the other way around.

Strength and Limitations

We conducted an EMA study to investigate within-subject associations between momentary affective states and naturally occurring exercise that provides high methodological standards (Kanning et al., 2013). An ambulatory assessment allows for an investigation with high ecological validity (Shiffman et al., 2008; Trull and Ebner-Priemer, 2013). Since we collected data for 20 days, we assume that the data accurately reflected the daily lives of the individuals. The assessment of both affect and naturally occurring exercise in real life led to a high external validity of our data. Another strength of our study is that we used a multidimensional measure of affect and thus took not just valence but also arousal and calmness into account. Wilhelm and Schoebi (2007) have shown that this three-dimensional assessment of affect is suitable and adequate for registering fluctuations in affect in real time (cf. Schimmack and Grob, 2000).

Despite these benefits, the decision to employ EMA comes at the expense of a limited experimental control of confounding variables. External factors (e.g., doctor's appointments) beyond affective states might have an impact on exercise duration. In addition, other events besides exercise (e.g., social conversations) might have an impact on affect in the evening. A methodological limitation of our study was that normality of the dependent variable cannot be assumed, since natural occurring exercise duration is a skewed variable. Yet another limitation of our study was that our sample consisted of university students. Thus, generalizations based on these results need to be made with caution, because they may be affected by selection bias. Furthermore, it may be that only individuals who were especially motivated to exercise regularly were attracted by our posters and leaflets, which is supported by the high values of naturally occurring exercises in the sample.

Implications for Future Research

Future research should investigate the bi-directional effects of affect on naturally occurring exercise and vice versa in a more controlled way. Most of all, it is important to create a design in which affect is assessed immediately before and after a person exercises in daily life (e.g., with an activity-triggered design). This allows identification of the temporal sequence of the association and more precise assessment of the underlying dynamic relationship between affective states and naturally occurring exercise. In addition, due to dense assessments there are fewer influences that might have an impact on affect or exercise as the dependent variable. It would also be interesting to examine the effect of naturally occurring exercise on affect and vice versa with varying time intervals (e.g., after 1 h, after 3 h) to examine how long the effects of affect or exercising last. Plus, exercise days could be compared to non-exercise days regarding the stability or enhancement of positive affective valence over the day. Experimental approaches will be needed to enable causal inferences. As a means of obtaining a randomized controlled trial, it might be useful to randomly assign individuals to activity conditions (Liao et al., 2015). To validate the self-report data of exercise duration, future studies should combine self-reports and objective data (accelosensors). Since affect is not the only variable to influence exercise behavior in daily life, the interplay between affective states and other important variables, such as intentions, should be taken into account in future studies. In addition, future research should investigate the bidirectional effects of affective states and exercise in initiating exercise bahavior in individuals who do not yet exercise. Our study emphasizes the importance of analyzing within-subject effects when investigating the relationship between naturally occurring exercise and affective states. Future intervention studies that aim to increase naturally occurring exercise should take situational variables such as momentary affective states into account. Furthermore, strategies for increasing positive affective valence should be considered as means of enhancing naturally occurring exercise.

CONCLUSION

The health message of this study clearly states that naturally occurring exercise behavior is associated with positive affective valence on a day level and with positive affective valence in the evening. The findings demonstrate that it would be worthwhile to focus more on within-subject analyses when analyzing the dynamic relation between affective states and naturally occurring exercise. Whether the affective state precedes the exercise behavior or is rather a response to exercise behavior is not quite clear on the day level. However, either way it might affect exercising in daily life, because positive affective states preceding exercising might facilitate the initiation and duration of exercising, whereas affective states following exercising might affect future exercise behavior by having an impact on expectations. We propose that inducing positive affect before exercising and, for example, a conscious focusing on positive affect after exercising could increase naturally occurring exercise. In addition, "feeling energized and awake" might be an important precondition for exercising. Momentary affective states should be taken into account in the creation of effective interventions to foster habitual physical exercise.

AUTHOR CONTRIBUTIONS

AS contributed to the conception and the design of the study. She analyzed and interpreted the data and did a first draw of the paper. She did a final approval. MK analyzed and interpreted the data and was revising the paper critically for important intellectual content. She did a final approval. RF contributed to the conception and design of the study. He was revising the paper critically for important intellectual content and did a final approval.

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SUPPLEMENTARY MATERIAL

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ORIGINAL RESEARCH
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Momentary Affective States Are Associated with Momentary Volume, Prospective Trends, and Fluctuation of Daily Physical Activity

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Several interventions aiming to enhance physical activity in everyday life showed mixed effects. Affective constructs are thought to potentially support health behavior change. However, little is known about within-subject associations between momentary affect and subsequent physical activity in everyday life. This study analyzed the extent to which three dimensions of affective states (valence, calmness, and energetic arousal) were associated with different components of daily activity trajectories. Sixty-five undergraduates' students (Age: $M = 24.6$; $SD = 3.2$; females: 57%) participated in this study. Physical activity was assessed objectively through accelerometers during 24 h. Affective states assessments were conducted randomly every 45 min using an e-diary with a six-item mood scale that was especially designed for ambulatory assessment. We conducted three-level multi-level analyses to investigate the extent to which momentary affect accounted for momentary volume, prospective trends, and stability vs. fluctuation of physical activity in everyday life. All three affect dimensions were significantly associated with momentary activity volumes and prospective trends over 45 min periods. Physical activity didn't fluctuate freely, but featured significant autocorrelation across repeated measurements, suggesting some stability of physical activity across 5-min assessments. After adjusting for the autoregressive structure in physical activity assessments, only energetic arousal remained a significant predictor. Feeling energized and awake was associated with an increased momentary volume of activity and initially smaller but gradually growing decreases in subsequent activity within the subsequent 45 min. Although not related to trends in physical activity, higher valence predicted lower stability in physical activity across subsequent 45 min, suggesting more short-term fluctuations in daily activity the more participants reported positive affective valence. The current analyses afford interesting insight into within-subject associations between momentary affect and activity-trajectories in everyday life. Energetic arousal emerged as the only meaningful predictor of physical activity in daily life after adjusting for autoregression. A significant effect of valence on short-term activity fluctuations might indicate that activity interventions would benefit from taking into account enhancement of positive affective valence in everyday life. Moments of enhanced valence may scaffold attempts helping inactive people to get started with daily activities and overcome periods of inactivity in everyday life.

Keywords: exercise, emotion, ambulatory assessment, ecological momentary assessment, activity-trends, affect

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INTRODUCTION

Strong evidence demonstrating health enhancing benefits of physical activity underscores the need for effective interventions to initiate physical activity behavior change (Physical Activity Guidelines Advisory Committee, 2008; Lee et al., 2012). Being physically active helps to prevent non-communicable diseases like coronary heart disease, type 2 diabetes, and some forms of cancer (World Health Organization, 2002; Wartburton et al., 2006). Despite its health relevance, most people don't reach the recommended volume of being physically active for at least for 150 min per week (Troiano et al., 2008).

To increase physical activity, most interventions have been informed by social-cognitive theoretical models, such as theory of planned behavior (Fishbein and Ajzen, 1975), or the transtheoretical model (Prochaska and Velicer, 1997). Despite their well-established theoretical foundation, however, interventions showed mixed success in enhancing physical activity (Prestwich et al., 2014). Although these behavior change theories implicitly consider affective influences, behavior change interventions focus mainly on cognitive and reasoned determination and disregard affective influences. Yet, several studies have shown that affective constructs are relevant not only to explain variations in physical activity but also to predict prospective activities (for an overview: Ekkekakis et al., 2013). Incorporating affective influences in health behavior interventions may improve intervention effects (Helfer et al., 2015). So far, however, within-subject effects of affective states on subsequent physical activity are not well understood. The current study used an ambulatory assessment approach to examine whether and to what extent momentary affective states are associated with different components of daily activity-trajectories. Ambulatory assessments allow the repeated assessments of individual changes in physical activity and affective states over time in everyday life (Ebner-Priemer and Trull, 2009).

Prior studies pointed to the importance of affect in predicting health related behaviors. For instance, a questionnaire study (Lawton et al., 2009) assessed affective and cognitive attitudes of 390 healthy adults at time one to predict self-reported behaviors at a 1 month follow-up assessment. The study revealed that, compared to cognitive attitudes, affective attitudes were significantly more powerful predictors of alcohol use, smoking, exercising, and fruit and vegetable consumptions at time 2. Associations of affect with prospective physical activity were analyzed in a recent systematic review (Rhodes and Kates, 2015). The authors included 24 studies that measured affect in response to an acute or regular bout of physical activity, and that assessed enacted or intended physical activity as the dependent variable. Positive changes in affect during moderate physical activity was prospectively linked to more activity behaviors, whereas post-exercise affective responses were unrelated with activity. Williams et al. (2012) used a longitudinal design to examine whether affective valence during a treadmill walk of 10 min predicted physical activity. One hundred sixty four healthy, low-active adults participated in this physical activity promotion trail. Positive affective valence reported during the brief walk predicted concurrent physical activity and self-reported lifestyle activity 6 months later.

Ample evidence supports the importance of affect in predicting either physical activity intention to be active or the behavior of subsequent activity (Rhodes and Nigg, 2011). Based on this evidence, we argue that affect should be considered alongside cognitive and reasoned determination as factors explaining behavior change in physical activity (Ekkekakis et al., 2013). Several issues require clarification, however: first, most studies analyzed affective reactions due to a specific exercise program or treadmill walking and used these affect-perceptions to predict the intention to or the behavior of subsequent physical activity. Physical activities in daily living such as going for a walk, gardening, playing with children, or making a cycling tour have hardly received attention, although such lifestyle activities make up a large part of the entire volume of physical activities. Increasing this type of activity is important to prevent health related diseases. For instance, a prospective cohort study with more than 400.000 individuals (Wen et al., 2011) indicated that 15 min of activity a day was associated with a 14% reduction in all-cause mortality risk, and with a 3 years longer life expectancy. Second, the design of most former studies did not allow for analyzing associations of momentary affective states and physical activities as a process unfolding over time. Consequently, we know little about within-subject changes in daily physical activities following prior momentary affective states.

According to the Activity-State Hypothesis (Rowland, 1998) physical activity in everyday life seems to follow an homeostatic mechanism, indicating stability in dynamic systems by the process of negative feedback. That means that physical activity (or energy expenditure) might be overall stable over time and that after high volumes of activity low volumes are probably following and vice versa. Thus, physical activity in everyday life is highly predicted by former activity. This oscillating pattern of activity needs to be taken into account when analyzing variations in daily physical activities over time. If we assume a substantial concurrent association between affect and physical activity, activity is likely elevated at that time point and will likely decrease across subsequent measurements. As a result, potential positive prospective effects of affect on physical activity will be attenuated or masked; where potential negative prospective effects of affect on activity would be enhanced. To adjust for such bias when predicting subsequent physical activity from affect reports, it is important to take into consideration prior volumes of physical activity at any predicted measurement point of activity. This allows for predicting prospective physical activity variations independent of prior volumes of activity. Incorporating moment-to-moment (autoregressive) associations of physical activity reflects also a meaningful dimension of physical activity itself, namely its fluctuation or stability across time. For physical activity interventions, it is now relevant to know how important this autoregressive structure is in influencing activity compared to affective determinants.

The current study examined the extent to which momentary affective states predict momentary volume, prospective trends, and stability vs. fluctuation in daily physical activity. We used an ambulatory assessment approach to capture individuals' momentary affective states and their physical activity in their daily lives. Based on the existing state of research (e.g., Kanning et al., 2013; Liao et al., 2015), we tested the hypotheses that valence and energetic arousal are positively whereas calmness is negatively associated with momentary volume of physical activity in daily life. We extended existing research in (1) analyzing to what extent the three different dimensions of affective states predicted prospective trends in physical activity, and (2) by investigating associations of momentary affect on stability vs. fluctuations of prospective physical activity across time. **Figure 1** provides examples for activity trends with high vs. low stability.

MATERIALS AND METHODS

Subjects

A convenience sample of 65 undergraduate students (57% females) participated in this ambulatory assessment study. The sample was recruited from a German university and had a mean age of 24.6 years ($SD = 3.2$). The data were part of another study, which have been presented elsewhere (Kanning, 2013), but the analyses here and the combination of physical activity and affective states are unique to this paper.

Before data recording, subjects were informed about the aim of our study, which was analyzing the association between physical activity and affective states. All of the subjects took part in the study voluntarily. They received no monetary compensation for their participation. Following the process of institutional ethical approval, all of the participants provided written informed consent. APA ethical standards were followed in the conduct of the study.

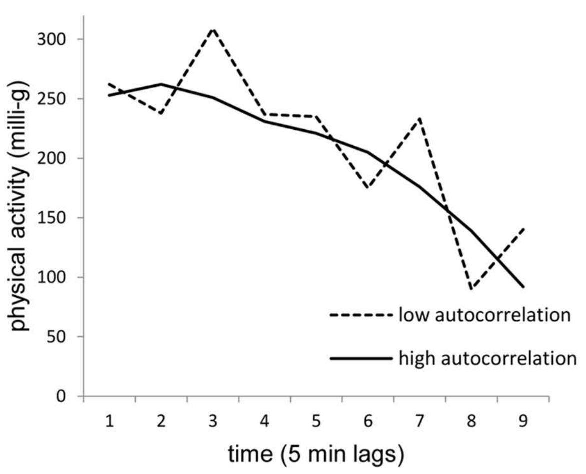

FIGURE 1 | Activity trajectories across time with low (broken line) and high (bold line) stability. The graph exemplifies trajectories with a negative time trend after adjusting for autocorrelation. Moment-to-moment changes increase with time, on average, resulting in a curvilinear shape of trajectories.

Ambulatory Assessment Procedure

Physical activity in daily living was measured continuously using a 3-way accelerometer (varioport-e; Becker Meditech, Germany) for 24 h. The varioport-e was started and then attached to each subjects' hip. Twenty-four hours later, subjects returned to the laboratory where data recording was stopped. Participants were allowed to take off the accelerometer when sleeping. Ratings for affect were assessed via electronic diaries (Palm, Tungsten E2). For this, the palmtop prompted subjects every 45 min during a defined 14-h daytime period (8:00am–10:00pm). If the person made no entry to the electronic diary, the palmtop beeped again 10 min later to remind the person to fill in the questionnaire. The assessment always took place on weekdays. We included only reports that were made within 10 min of the first beep, which was the case for 87.9% of the reports. The average latency between the beep and the report was $M = 2.15$ min ($SD = 3.96$).

Measures

Affective States

Momentary affective states were measured by using the Short Mood Scale (Wilhelm and Schoebi, 2007), which is based on the Multidimensional Mood Questionnaire, for which validity and reliability has been demonstrated (Steyer et al., 1997). The short scale is the only instrument that has been explicitly developed and evaluated for use in ambulatory assessment. The scale contains six items that assess the intensity of three dimensions of affective states that are ordered as semantic differentials: *valence* (unwell vs. well, discontent vs. content), *calmness* (relaxed vs. tense, calm vs. agitated), and *energetic arousal* (tired vs. awake, without energy vs. full of energy). Subjects answered the question "At this moment, I feel..." by moving a slider from the left end (e.g., unwell) to the right end (e.g., well) of the bipolar scale. Scores for each subscale were obtained by averaging the item scores, which resulted in a range from 0 to 5. Wilhelm and Schoebi (2007) investigated homogeneity at the between-person and the within-subject level. The reliability coefficient for the between-person level reached 0.92 for valence and 0.90 for energetic arousal and calmness. The reliability coefficient for the within-subject level reached 0.70 for valence and calmness and 0.77 for energetic arousal. Based on this finding, the reliabilities both resulted in good internal consistencies.

Physical Activity in Daily Living (PA)

The varioport-e measured acceleration (defined as change in velocity over time) and describes the intensity, the rate of occurrence and the duration of an actual physically active episode. Acceleration was measured in milli-g, for each minute in the 24-h period. All offline analyses and artifact-checks were performed by the interactive software package "Freiburg Monitoring System" according to a published procedure (Myrtek, 2004).

Data Analysis

The data featured multiple dependencies, with activity measurements (level 1) being nested within affective state assessments at 45-min intervals (level 2), which were nested within participants (level 3). We therefore analyzed the data using multilevel models with three levels. To examine whether momentary affect predicted momentary activity volume, prospective trends, and fluctuation, we used a multilevel model in which we estimated a growth parameter for each 45-min interval for which participants reported about their affective states. To approximate a normal distribution, reduce short-term fluctuations, and reduce the amount of data, we aggregated activity scores for each 5 min interval, and then computed the moving average over series of three consecutive 5-min activity aggregates. To assess momentary volume of activity and prospective trends, and their associations with prior affect variables, we first ran a model that did not adjust for the autoregressive structure in daily physical activity (model 1). We then extended this model to incorporate an autoregressive structure (model 2). Comparing these models revealed to what extent associations between affect and different components of daily activity-trajectories were accounted by prior activity volumes.

In model 1, we tested a growth model at level 1, with the nine moving average activity scores (45/5 = 9) changing as a function of time, for each 45-min interval between affect measurements. Minor deviations from 45-min were possible due to response latency. This model allowed for momentary activity volume and prospective trends to vary within person across 45-min lags. For example, activity could increase over the 45 min, and then decrease across the subsequent 45 min, before remaining stable across the third subsequent 45-min interval. The level-1 equation for model 1 can be written as:

$$\text{Activity}_{\text{i+1jk}} = b_0\left(\text{constant}_{\text{ij}}\right) + b_1\left(\text{time}_{\text{ijk}}\right) + e_{\text{ijk}}$$

The activity following one time unit (5-min) after a particular time point i, during the 45-min lag j of person k, is represented by a constant b_0, capturing the momentary activity volume at the beginning of the 45-min lag, a time parameter b_1, reflecting trends in activity across the 45-min time lag, and an error term e_{ijk}. A positive time trend reflects increasing activity across a particular 45-min period, and a negative time trend reflects decreasing activity across a 45-min period, as exemplified in **Figure 2**. We also examined extended growth models, including squared and cubic time trends to capture curvilinear associations. Because these models did not significantly improve the predictions, we report only the linear growth models.

At level 2, we then used the affect reports at each 45-min interval to explain variability in (a) momentary activity volume, and (b) trends of activity across 45 min intervals.

Level-2 equations (model 2):

$$b_0 = g_{00} + g_{01}\left(\text{affect}_{\text{jk}}\right) + u_{00}$$

$$b_1 = g_{10} + g_{11}\left(\text{affect}_{\text{jk}}\right) + u_{01}$$

Parameter g_{01} reflects the extent to which momentary activity volume at the beginning of the 45-min lag j of person k is a function of that person's affect report at the beginning of lag j. The estimate for g_{11} captures the association of a person's affect report at the beginning of lag j, and his or her trend in activity across that lag. Finally, u_{00} and u_{01} represent residual variance of the constant and the linear growth parameter.

In model 2, we added the first order autoregressive parameter to capture the stability of activity across time. This parameter captures moment-to-moment stability (or instability), and adjusts the time trajectories for regression toward the mean by eliminating the effects of prior volumes of activity. Thus, in this model, the time parameter no longer captures constant linear trends of activity across 45-min intervals, but the extent to which activity changes between 5-min activity measurements become increasingly positive or negative over the 45-min intervals. The full level-1 equation (model 2) can be written as follows:

$$\text{Activity}_{\text{i+1jk}} = b_0\left(\text{constant}_{\text{ij}}\right) + b_1\left(\text{time}_{\text{ijk}}\right) + b_2\left(\text{activity}_{\text{ijk}}\right) + e_{\text{ijk}}$$

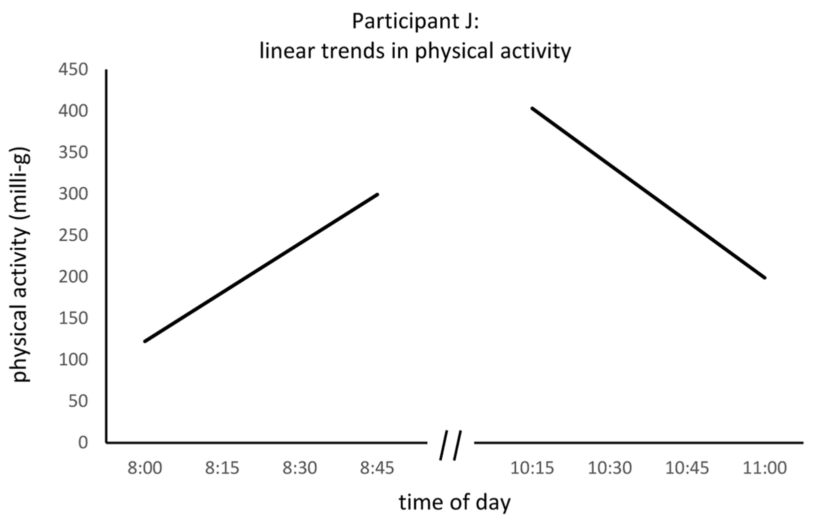

FIGURE 2 | Examples of linear activity trends across time for two 45-min periods of participant J. The graphs exemplify 45-min trends in activity, reflecting increases (left slope) and decreases (right slope) in the activity of the same participant on the same day.

In addition to the equation for model 1, the equation now includes an autoregressive parameter b_2, capturing stability in activity across time.

In addition to regressing momentary activity volume (g_{01}) and trends of activity across 45 min intervals (g_{11}) on affect reports, we also estimated whether stability or fluctuation in activity across time was predicted by affect (g_{21}).

Level-2 equations (model 2):

$$b_0 = g_{00} + g_{01}\left(\text{affect}_{\text{jk}}\right) + u_{00}$$

$$b_1 = g_{10} + g_{11}\left(\text{affect}_{\text{jk}}\right) + u_{01}$$

$$b_2 = g_{20} + g_{21}\left(\text{affect}_{\text{jk}}\right) + u_{02}$$

The estimate for g_{21} captures the association of a person's affect report and stability in her activity across repeated measurements, and u_{02} represents the residual variance of the autoregressive parameter across 45-min lags.

Importantly, the affect predictors were centered at each individual's mean affect across all measurements, and therefore, the estimates for these parameters reflected within-subject associations between affect and activity volumes, and within-subject stability. We ran several models in which only one (as shown in the level-2 equations above) or multiple affect components (valence, energetic arousal, and calmness) were tested as predictors of momentary activity volume, trends, and stability estimates. In the model with all three affect components, no significant effects emerged that were not significant in the models testing each component separately, and we therefore report the results from the combined test.

RESULTS

Descriptive Statistics

The average activity level across individuals was $M = 90.25$ milli-g (between-subject $SD = 27.31$ milli-g), while the median was $Md = 54.99$ milli-g (between-subject $SD = 20.31$ milli-g). For comparison purposes, jogging episodes produce approximately 1,000 milli-g/min, walking episodes produce approximately 350 milli-g/min, and sheer sitting episodes produce approximately 10 milli-g/min (Kanning et al., 2013). The results for testing level-1 predictors largely confirmed our expectations. Estimating linear trajectories across 45-min periods (model 1) indicated no significant overall trend ($b = -0.163$, $t = 0.565$, $p = 0.574$). The average activity change between repeated measures was 0.14 ($SD = 0.82$) and did not differ significantly from zero (95% CI = –0.07; 0.35), thus suggesting that activity fluctuated around a habitual level. Examining first order autoregression suggested significant stability in activity across time ($b = 0.718$, $t = 40.760$, $p < 0.001$). The average level of valence was $M = 3.56$ (between-subject $SD = 0.60$), of energetic arousal $M = 3.02$ (between-subject $SD = 0.56$), and calmness $M = 3.43$ (between-subject $SD = 0.60$), indicating moderate to high values of momentary affect with substantial within-subject variation (cf. **Table 1**).

Did Momentary Affect Predict Momentary Activity Volume, Prospective Trends, and Stability vs. Fluctuation in Daily Physical Activity?

Momentary activity volume, prospective trends, and stability varied significantly across 45-min intervals ($ps < 0.001$), but autocorrelation and time trends did not vary across individuals ($ps > 0.421$).The results for the level-2 for model 1 and model 2 are summarized in **Table 2**.

Estimates for model 1 suggested that at times reports of more positive affective valence ($b = 11.797$, $p = 0.005$) less calmness ($b = -12.176$, $p = 0.001$), and more energetic arousal ($b = 20.521$, $p < 0.001$), were associated with higher momentary activity. Affective states also predicted activity trends across time. Reports of more positive affective valence ($b = -1.486$, $p = 0.014$), and more energetic arousal ($b = -0.779$, $p = 0.049$) were associated with activity decreases over the subsequent 45-min intervals. A marginally significant parameter suggested that reports of more calmness were associated with activity increases ($b = 1.031$, $p = 0.055$). Importantly, the pattern of estimates for prospective trends was complementary with that of activity volumes, suggesting a trend toward mean activity after activity peaks and low points.

When taking into account prior activity volumes in model 2, a significant association between affective states and activity trends resulted only for energetic arousal. In cases when participants reported more energetic arousal, activity changes trended toward decreases, whereby the decrease was initially small but gradually growing across the subsequent 45-min interval ($b = -0.610$, $p = 0.013$).

Positive affective valence was associated with less positive (more negative) autoregressive parameter estimates ($b = -0.031$, $p = 0.026$), suggesting that within 45-min intervals after

TABLE 1 | Descriptive statistics of the three dimensions of affective states and physical activity.

Variable	Between-subject		Within-subject variability		Minimum	Maximum
	Mean	*SD*	Mean	*SD*		
Physical activity	90.25	27.31	104.94	47.42	0	1330.71
Valence	3.56	0.6	0.85	0.31	0	5
Energetic arousal	3.02	0.56	1.16	0.29	0	5
Calmness	3.43	0.6	0.89	0.33	0	5

Within-subject variability is indicated as standard deviations.

TABLE 2 | Within-subject relations between the three dimensions of affective states (valence, calmness, and energetic arousal) and different components of daily activity-trajectories (momentary volume, trend, and stability).

Level 2 parameter	Momentary activity volume (intercept)			Trend (time slope)			Stability/fluctuation (activity slope)		
	Coefficient	*t*-ratio	*p*-value	Coefficient	*t*-ratio	*p*-value	Coefficient	*t*-ratio	*p*-value
Model 1									
Valence	11.797	2.827	0.005	−1.486	2.466	0.014			
Calmness	−12.176	3.264	0.001	1.031	1.920	0.055			
Energetic arousal	20.521	7.502	<0.001	−0.779	1.974	0.049			
Model 2									
Valence	6.955	1.417	0.157	−0.489	1.297	0.195	−0.031	2.224	0.026
Calmness	−7.992	1.814	0.070	0.206	0.613	0.540	0.012	0.904	0.366
Energetic arousal	19.892	6.174	<0.001	−0.610	2.474	0.013	−0.008	0.793	0.428

participants reported better feelings, physical activity was less stable, or in other words, fluctuated more strongly across 5-min measurements.

DISCUSSION

This ambulatory assessment study was among the first to investigate different components of daily activity-trajectories (momentary volume, prospective trends, and stability vs. fluctuation) and to analyze to what extent affective states predicted trends and stability independent from prior volumes of activity. The results suggested that momentary affective states were significantly associated with momentary volume of physical activity. Furthermore, energetic arousal is negatively associated with prospective activity trends, whereas valence is positively associated with prospective fluctuations of physical activity.

To our knowledge, trajectories in daily physical activity have hardly been investigated in detail. So far, several studies investigated patterns of physical activity, analyzing how much time the sample was sedentary or physically active with moderate or high intensity (e.g., Evenson et al., 2015; Hooker et al., 2015). Although these studies described the quantity of different activity volumes, they did not analyze trajectories in physical activity. The findings of the presented study suggested that the volume of physical activity in daily life varies over time without significant short-term trends. Thus, physical activity in everyday life oscillate around a habitual level, supporting the Activity-State Hypothesis (Rowland, 1998). The Activity-State Hypothesis has been predominantly used to explain compensatory change in one domain (e.g., leisure-time), when physical activity is being increased or decreased in another domain (e.g., school, at work; for an overview Gomersall et al., 2013). Although the presented study investigated daily physical activities without distinguishing between different domains, the findings suggested that physical activity might follow an autoregressive structure. To create effective interventions for enhancing physical activity, it is important to understand whether and to what extent affective states can influence daily physical activity in addition to the autoregressive structure of activity.

Valence, energetic arousal, and calmness were all significantly associated with the momentary volume of daily life activity. These findings converge with former ambulatory assessment studies on associations between physical activity and affective states in everyday life. However, most of these former studies tested the effects of physical activities on affective states, rather than vice versa (for an overview: Kanning et al., 2013). Nevertheless, a recent systematic literature review examined six studies that tested whether affective states predicted subsequent physical activity (Liao et al., 2015). For instance, in a 12 h- ambulatory assessment with 124 healthy adults between 18 and 73 years, Schwerdtfeger et al. (2010) assessed physical activity continuously and affective states every hour during waking hours. The authors examined associations between momentary affect and the average activity volumes during four subsequent periods (1, 1–5, 1–15, and 1–30 min). Their results suggested that the more positive subjects felt, the more active they were during all four subsequent activity-periods. However, the other studies included in Liao's et al. (2015) review did not consistently report positive associations, suggesting overall mixed support for the assumption that positive feelings lead to physical activity.

The focus of the current research was on different components of daily activity-trajectories and whether these activity variations were predicted by affective states in daily life. The findings of model 1 suggested that patterns of change in momentary activity volumes corresponded with prospective activity trends. Feeling well (valence), full of energy (energetic arousal) and agitated [calmness (–)] were each associated with a high level of momentary volume of the physical activity aggregated across the 5 min directly following the e-diary assessment and with decreases in activity during the subsequent 45 min. These results suggested a trend toward mean activity after activity peaks. To address that autoregressive structure and because high activity would naturally regress to the mean and therefore spuriously inflate negative associations between affect dimensions and activity, we integrated an autoregressive parameter in model 2, which allowed us to predict activity-trends independently from prior volumes of activity. This model 2 revealed that calmness and valence were no longer meaningful predictors of activity changes. However, energetic arousal remained a significant predictor for momentary volume and prospective trends of daily physical activity. Thus, when an individual felt highly energized, his or her activity volume was high and decrease across the subsequent 45 min interval. Interestingly, decreases in activity were initially small but gradually growing across the subsequent 45-min interval. So first, participants hold their activity volume followed by an increasing decrease in subsequent physical activity (cf. **Figure 1**).

Beside the function to control for the presumed biological mechanism, the autoregressive parameter itself captures stability of physical activity across time. The significant and negative association of valence pointed to more fluctuations in activity the better the person felt before. Positive affective valence appears to foster changes in activity volumes in everyday life. According to Fredrickson's *broaden and build model* positive emotions (e.g., joy, contentment, and love) broaden individual's repertoire for action to seek new goals, for instance, and expend individual's resources and friendships (Fredrickson, 1998). Thus, individuals are ideally situated to think and act in ways that promote both resource building and involvement with approach goals. Although this model is about the effect of general positive emotions and does not reflect on potential effects of momentary affect in everyday life, it may hint at how positive affective valence may operate in daily life. It may be that positive feelings support people more readily engaged in doing the things that they want or have to do in their everyday life (e.g., run some errands, going for a walk), and therefore, lead to more frequent changes of the specific types of activity. In most cases, such engagement is associated with an increased variety of physical activity. The effect of positive affective valence on prospective physical activity may also be interesting for physical activity interventions. It is a challenge for inactive people to bring themselves to an active lifestyle. If positive feelings help individuals to get started with daily activities, it may be easier for them to overcome periods of inactivity in everyday life. Thus, interventions to increase daily activities may be more effective if they provide strategies for emotion regulation in addition to prescriptions how to be active in daily life. If an inactive person is able to experience positive feelings, it will be more likely that this person engages in the recommended activity. To enhance positive feelings in everyday life, an intervention may support inactive individuals in selecting and modifying everyday life situations, which are individually associated with positive feelings and which may be suitable to be physically active.

Some limitations need to be taken into account when interpreting the results. First, physical activity and affective states were assessed only during the course of a single day. To better support the existence of a biological mechanism and to analyze trajectories in daily physical activity, the assessment period needs to cover more than 1 day. Second, this study involved only university students, which resulted in a sample that is both younger and of a higher socioeconomic status than the overall population. Generalizations based on these results thus need to be done with caution. Lastly, this study did not assess important environmental (e.g., weather, physical environment) or psychosocial (e.g., being together with meaningful people, social support) factors, which might have influenced both momentary affect and physical activity.

CONCLUSION

Broad evidence indicates that affect is an important predictor of physical activity motivation and behavior. Physical activity interventions should therefore make use of affect and related constructs to improve their effectiveness to induce behavior change. Our results suggest that important dimensions of momentary affect – valence, calmness, and energetic arousal – were all significantly associated with momentary volume and prospective trends in physical activity in daily life. After adjusting for the autoregressive structure, and thereby adjusting for prior activity levels when predicting prospective physical activity, calmness and valence were no longer significantly related to prospective activity trends, whereas energetic arousal remained a significant predictor. Energetic arousal thus emerged as the only meaningful predictor of momentary activity volumes, and of prospective trends in activity changes. Specifically, feeling highly energized predicted initially smaller changes that grow larger over the span of the 45 min periods. In addition, positive affective valence was predictive of short-term activity dynamics, as reflected by a significant association with more short-term fluctuations (or less stability) in everyday life activity volumes. These findings could imply that interventions designed to enhance daily physical activity might be more effective if they incorporated strategies to foster positive affective valence in everyday life. Strategies to enhance positive feelings may help inactive people to initiate change their inactive lifestyles.

AUTHOR CONTRIBUTIONS

MK made substantial contributions to the design of the work and conducted the study. MK interpreted the data, drafted the work, and gave the final approval of the version to be published. DS made substantial contributions to the analysis and the interpretation of the data. DS revised the work critically for important intellectual content and gave final approval of the version to be published. MK and DS both agreed to be accountable for all aspects of the work ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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Within-Subject Associations between Mood Dimensions and Non-exercise Activity: An Ambulatory Assessment Approach Using Repeated Real-Time and Objective Data

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A physically active lifestyle has been related to positive health outcomes and high life expectancy, but the underlying psychological mechanisms maintaining physical activity are rarely investigated. Tremendous technological progress yielding sophisticated methodological approaches, i.e., ambulatory assessment, have recently enabled the study of these mechanisms in everyday life. In practice, accelerometers allow to continuously and objectively monitor physical activity. The combination with e-diaries makes it feasible to repeatedly assess mood states in real-time and real life and to relate them to physical activity. This state-of-the-art methodology comes with several advantages, like bypassing systematic distortions of retrospective methods, avoiding distortions seen in laboratory settings, and revealing an objective physical activity assessment. Most importantly, ambulatory assessment studies enable to analyze how physical activity and mood wax and wane within persons over time in contrast to existing studies on physical activity and mood which mostly investigated between-person associations. However, there are very few studies on how mood dimensions (i.e., feeling well, energetic and calm) drive non-exercise activity (NEA; such as climbing stairs) within persons. Recent reviews argued that some of these studies have methodological limitations, e.g., scarcely representative samples, short study periods, physical activity assessment via self-reports, and low sampling frequencies. To overcome these limitations, we conducted an ambulatory assessment study in a community-based sample of 106 adults over 1 week. Participants were asked to report mood ratings on e-diaries and to wear an accelerometer in daily life. We conducted multilevel analyses to investigate whether mood predicted NEA, which was defined as the mean acceleration within the 10-min interval directly following an e-diary assessment. Additionally, we analyzed the effects of NEA on different time frames following the e-diary prompts in an exploratory manner. Our results revealed that valence significantly and positively predicted NEA within persons ($p = 0.001$). Feeling more energetic was associated with significantly increased NEA ($p < 0.001$), whereas feeling calmer was associated with significantly decreased NEA ($p < 0.001$) on the within-person level. The analyses on different time frames of NEA largely confirmed our findings. In conclusion, we showed that mood predicted NEA within adults but with distinct magnitudes and directions of effects for each mood dimension.

Keywords: ambulatory assessment, ecological momentary assessment, mood, affective states, physical activity, non-exercise activity, activities of daily life, accelerometry

INTRODUCTION

Physical activity is an important determinant of human health, and being physically active has been shown to contribute to the prevention of and recovery from severe somatic and psychiatric diseases (for an overview refer to Pedersen and Saltin, 2015). Specifically, both engaging in exercise (such as swimming, playing football, working out at the gym) and living a physically active life comprising high levels of non-exercise activity (NEA; e.g., daily routines of walking to the office, biking for transport, climbing stairs) have been related to high health expectancy, for example reductions in the risk of cardiovascular disease (Healy et al., 2008; Wen et al., 2011). A better understanding of the psychological determinants of physical activity is of central significance to enhancing health promoting lifestyles with less sedentary behavior. According to behavioral theories, affective experiences play an important role in human behavior. In other words, activities related to positive affective experiences are supposed to be more likely to be repeated than those associated with a negative mood.

Although a large body of intervention studies have investigated between-subject effects of exercise on mood (for an overview refer to Reed and Ones, 2006; Reed and Buck, 2009), unfortunately, there has been a lack of research on the within-subject associations between physical activity and mood. Between-subject designs do not reveal how physical activity and mood wax and wane within people over time. Therefore, the between-subject findings that people who are on average more active than others feel better on average than others provide no evidence that there is a within-subject timely relationship between both of those processes, i.e., that within subjects, episodes of activity are related to good moods and that episodes of low activity are related to bad moods. From a more theoretical perspective, between-subject associations cannot be translated into within-subject relationships (Aarts et al., 2014), which implies that if the topic of interest is how mood maintains physical activity, a within-subject assessment approach is mandatory.

To investigate within-subject associations of physical activity and mood in participants' everyday lives, ambulatory assessment is currently the most promising and recommended state-of-the-art technique (Kanning et al., 2015). The use of e-diaries on smartphones to repeatedly assess mood states in real-time and of accelerometers to continuously and objectively monitor activity provides several advantages. It enables researchers to (a) assess the dynamic and time-dependent interplay between mood and physical activity (Ebner-Priemer and Trull, 2009); (b) assess mood in real time and thus bypass the systematic distortions observed in retrospective methods (Stone et al., 2002; Fahrenberg et al., 2007); (c) avoid the distortions produced by laboratory settings (Bussmann et al., 2009); and (d) increase the validity of physical activity assessments compared with participant self-ratings (Prince et al., 2008; Adamo et al., 2009).

Over the past decade, several research groups have used ambulatory assessment approaches to study within-subject effects of physical activity on mood in everyday life. Schwerdtfeger et al. (2008) found higher intensity and/or duration of everyday life activity to be associated with higher positive activated affect in 124 healthy participants over 12 assessment-hours. Significant positive effects of physical activity on energetic arousal and a significant negative effect on calmness were shown by Kanning et al. (2012) in a sample of 44 undergraduates over 24 h. In 2013, Bossmann et al. showed significant positive effects of physical activity on energetic arousal and valence in 77 university students over the course of 24 h. Kanning (2013) showed physical activity to be positively related with subsequent ratings of valence and energetic arousal as well as negative effects of physical activity on calmness in a sample of 87 undergraduates. In 2015, Kanning et al. revealed significantly heightened energetic arousal and more agitation (calmness) following physical activity over 3 days in adults. Dunton et al. (2015) found social interaction and physical context (i.e., being outdoors) to moderate the effects of physical activity on mood.

Although the abovementioned studies show increasing evidence for physical activity affecting mood within subjects and a large body of treatment studies have found effects of exercise on mood (for a discussion we refer to Schlicht et al., 2013), the within-subject impact of mood on physical activity remains largely unknown. This is surprising because psychomotor retardation has been conceptualized as a consequence of major depressive disorder ever since and many studies showed limited physical activity in depressed patients (Burton et al., 2013; Reichert et al., 2015). Thus, research in this direction seems very promising.

Unfortunately, only very few within-subject studies have investigated the predictive value of mood on non-exercise activity (Liao et al., 2015). In 2007, Carels et al investigated the associations of mood and exercise in a sample of 36 obese adults who participated in a behavioral weight loss program. Mood was assessed every morning and every evening as well as prior to and after each bout of exercise over at least 4 weeks within the weight loss program. Both mood and exercise data (i.e., duration, intensity and type) were collected via participants' self-reports in diaries. Carels et al. focused on the investigation of mood-exercise associations and therefore did not take non-exercise activity into account. Regarding the effects of mood on exercise, Carels et al. (2007) found mood in the morning to significantly increase the initiation of exercise on the same day both on the within- and between-person level. However, mood assessed in the morning was not related to either the duration or the intensity of exercise.

Dunton et al. (2009) reported associations between affective factors and non-exercise activity in 23 physically inactive adults aged 50 years and above. The adults were asked to complete electronic diaries in the morning, at midday, in the afternoon and in the evening to report on positive/negative affect, energetic arousal and types of non-exercise activity, among others. Dunton et al. (2009) found an increase in positive affect and a decrease in negative affect at $t-1$ to be associated with significantly increased moderate-to-vigorous physical activity at the following assessment (t). However, the trend in the affect dimension of energetic arousal, i.e., feeling more energetic and less tired being related to enhanced levels of non-exercise activity, lacked significance. Dunton et al. (2014) conducted an ambulatory assessment study to investigate whether mood does affect physical activity in 119 children aged 11 to 13 years. They analyzed how mood ratings on e-diaries influenced accelerometer-measured moderate-to-vigorous physical activity within the 30 min following the prompts. Although increased levels of energy and decreased ratings of fatigue were associated with increases in moderate-to-vigorous physical activity, the positive and negative affect ratings were not related to subsequent physical activity.

Schwerdtfeger et al. (2010) analyzed the effects of mood on physical activity across a 12-h period in a sample of 126 adults mainly comprising students. In their study, Personal Digital Assistants (PDAs) randomly queried for mood approximately 12 times, and physical activity was assessed using accelerometers attached to participant's ankles. Schwerdtfeger et al. (2010) parameterized physical activity by applying the categories sedentary, light, moderate, and vigorous activity based on thresholds using unit counts. Moreover, they averaged the different time frames of physical activity following mood assessments, namely 1 min, 1 to 5 min, 1 to 15 min, and 1 to 30 min. Positive activated affect was significantly associated with physical activity across all aggregated time frames, i.e., the more the participants felt good and energized, the more they were physically active. In addition, low negative affect significantly predicted higher physical activity within the 15 and 30 min following a mood assessment. In addition, Schwerdtfeger et al. (2010) found mood to influence different intensity levels of physical activity, showing an inverse association between enhanced mood and sedentary periods. In other words, higher positive activated affect and lower negative affect led to less sedentary behavior. Heightened positive activated affect and diminished negative affect predicted moderate to vigorous physical activity as well.

Wichers et al. (2012) analyzed the associations between self-rated physical activity and mood in 504 female twins who filled out booklets when triggered by a digital wrist watch approximately 10 times per day throughout a study period of 5 days. Their hypotheses were mainly focused on the effects of increases in physical activity on mood. Interestingly, their data suggested that increases in physical activity followed a decrease in positive affect. However, this finding showed significance only for the positive affect that was rated three prompts prior to the increase in physical activity. Moreover, the finding could not be replicated in both groups of twins. Mata et al. (2012) compared the associations of physical activity and mood between 53 depressed patients and healthy controls. Over 7 days, the participants rated mood and physical activity on palmtops approximately 8 times per day. Mata et al. (2012) found positive affect to increase before bouts of physical activity and to decrease afterwards but no effects of negative affect on physical activity in both depressed and healthy participants. This finding implies a peak of positive affect at the time participants were physically active. However, as Mata et al.'s study (2012) was based on self-reported physical activity, the exact time points of activity are not known, and therefore suggestions of the exact temporal course of physical activity and mood remain unclear.

To sum up, the results of these studies suggest that an increase in positive affect within subjects is followed by enhanced physical activity in everyday life, whereas negative affect does not necessarily predict physical activity; feeling more energetic and less tired may increase physical activity. However, these findings are limited and inconclusive (for a discussion refer to Liao et al., 2015). Moreover, the abovementioned studies had methodological limitations.

In detail, Liao et al. (2015) criticized (a) the convenient recruiting strategies such as studying volunteers from a university, (b) the short study periods of a few hours or days, and (c) the rare use of accelerometers to objectively assess physical activity, i.e., only in two studies accelerometers were used (Schwerdtfeger et al., 2010; Dunton et al., 2014) whereas the other four studies were based on participant self-reports. This previous point is particularly important as self-reported physical activity has been shown to be only modestly related to objectively assessed physical activity (Prince et al., 2008; Adamo et al., 2009). Thus, Liao et al. (2015) identified the need for (a) investigations of representative community-based samples, (b) long assessment periods exceeding at least 1 day, and (c) assessments using accelerometers and e-diaries and reports on missing data. Moreover, Schwerdtfeger et al. (2010) raised (d) the issue of temporal resolution, i.e., investigating how mood and physical activity are interconnected over time. Unfortunately, in previous studies, mood was mostly assessed via self-report, and therefore it was impossible to investigate the associations with a high temporal resolution. Specifically, when assessing mood and physical activity only at 8 time points during the day, for example, time-lagged analyses remain very limited due to the large temporal offset between mood ratings and physical activity reports. However, these investigations are important to garner a deeper understanding of how mood affects physical activity over time, e.g., in which time frames mood influences physical activity.

To investigate how mood is associated with subsequent non-exercise activity and to overcome the methodological limitations of the very few existing studies on this issue, we conducted an ambulatory assessment study (a) in a large community-based sample of adults (b) over the course of 1 week. We (c) objectively assessed non-exercise activity (via accelerometer) and queried mood repeatedly (i.e., valence, energetic arousal and calmness) in real time and real life (using electronic diaries on smartphones). To investigate (d) which time frames of physical activity are associated with the mood-dimensions valence, energetic arousal and calmness, we conducted explorative analyses.

We hypothesized a positive relationship between both mood dimensions, valence and energetic arousal, and subsequent non-exercise activity. Given the temporal order, this does imply that valence (hypothesis I) and energetic arousal (hypothesis II) would predict non-exercise activity. Moreover, we hypothesized that calmness was associated with subsequent non-exercise activity (hypothesis III). As the effects of the mood dimension of calmness on physical activity have not yet been investigated, we stated a nondirectional hypothesis.

MATERIALS AND METHODS

Participants

The sample for the current analyses was derived from the ongoing URGENCY study (Impact of Urbanicity on Genetics, Cerebral Functioning and Structure and Condition in Young People) implemented at the Central Institute of Mental Health in Mannheim (CIMH), Germany. The psychiatric-epidemiological center (PEZ) at the CIMH was responsible for recruiting participants aged between 18 and 28 years. The current sample was drawn from the municipalities of Mannheim, Ludwigshafen, Heidelberg, Weinheim, and the Rhine-Neckar district containing parts of the Forest of Odes in the period from December 2014 to September 2015. Monetary compensation was provided for participation in the URGENCY study. Participants with moderate to severe impairment of intelligence, participants unable to provide consent or with legal incapacity and participants with acute diseases were excluded. Additional exclusion criteria were a lifetime history of cardiovascular, chronic endocrine, immunological, or clinically manifested mental disorders. To enable the exclusion of exercise periods and thereby focus our analyses on non-exercise activity, only data from participants who reported on their exercise activities within the study period were included. Of the initial 106 participants' datasets, 9 were excluded for missing accelerometer data (lost devices, incomplete recordings, etc.). Furthermore, 3 datasets were excluded because of the substantial amount of time that the accelerometer was not worn or because the e-diary compliance was below 30%. One dataset was additionally excluded because of the shifted diurnal rhythm of the participant resulting from shift work. Finally, the analyzed sample comprised 93 participants (62.4% female) with a mean age of 23.4 years ($SD = 2.7$); their mean BMI was 22.8 kg/m^2 ($SD = 3.6$).

Ambulatory Assessment Procedure

First, participants were instructed on how to use the smartphone (Motorola Moto G[1]) and accelerometer (Move-II[2]) during an extensive briefing consisting of individual device tests at the PEZ. Thereafter, they carried both devices in their everyday life for seven consecutive days. Mood was assessed every day from 7:30 to 22:30, applying a mixed sampling strategy implemented on the Android smartphones using the experience sampling software movisensXS (version 0.6.3658)[2].

In practice, participants were prompted every 40 to 100 min from 7:30 to 22:30 by an acoustic, vibration and visual signal on the smartphone; that is, they were invited to complete e-diary ratings at least 9 and up to 22 times per day. E-diary prompts could be postponed for 5, 10 or 15 min. In detail, e-diary assessment triggers were GPS-based and time-based. Since previous investigations revealed that standard approaches (e.g., time-based sampling) are likely to miss episodes of high non-exercise activity which occur rarely in everyday life (Ebner-Priemer et al., 2013), we used GPS-triggered e-diaries to optimize the sampling strategy (Dorn et al., 2015). Specifically, assessments were triggered every time the participants covered distances above 0.5 km. Moreover, the time-based sampling initiated prompts at fixed times (8:00 and 22:20) and additionally at least every 100 min from the preceding prompt (time-out trigger); it inhibited triggers within 40 min of the preceding prompt.

We aimed to focus the analyses on non-exercise activity. Hence, when the participants returned the devices at the PEZ after their study week, they were asked to report on their performed bouts of exercise within the assessment period (i.e., exercise duration, point in time) to enable the exclusion of these time frames from the analyses. To optimize participants' recall, we applied an approach following the idea of the Day Reconstruction Method (Kahneman et al., 2004). In practice, participants were shown the locations where they had stayed within the study period (tracked via smartphone) on a map. The participants were asked to label the locations (such as at home, at work, in the park, in the gym) to facilitate the recollection of exercise activities.

Measures

Non-exercise activity was assessed using the triaxial acceleration sensors of the move-II[2] (measurement range: +/−8 g; sampling frequency: 64 Hz; resolution: 12 bits; storage: internal memory card). Participants attached the devices at their right hip during the day for the entire study period except when sleeping. To assess mood, a short scale comprising two bipolar items for the mood dimensions valence, energetic arousal, and calmness, respectively, was administered in the e-diaries. This instrument was based on the Multidimensional Mood Questionnaire (Steyer et al., 1997) and was developed and evaluated by Wilhelm and Schoebi (2007) for the purposes of ambulatory assessment studies. They showed good psychometric properties on the between-person level with reliability coefficients of 0.92 for

[1]Motorola moto g. http://www.motorola.com/us/products/moto-g. Accessed 07 Feb 2016.

[2]Movisens GmbH. http://www.movisens.com/. Accessed 07 Feb 2016.

valence (items: unwell to well, discontent to content) and 0.90 for both energetic arousal (items: energy to full energy, tired to awake) and calmness (items: tense to relaxed, agitated to calm) and coefficients of 0.70 (valence and calmness) and 0.77 (energetic arousal) for the within-person level. Hence, this short scale was appropriate to assess within-person dynamics of mood over time in everyday life on e-diaries. In our study, visual analogue scales (0–100) were used. Additionally, the items were presented in reversed polarity and in a mixed order, as recommended by Wilhelm and Schoebi (2007).

Analyses

First, we processed the accelerometer data computing Movement Acceleration Intensity [milli-g/min], i.e., the mean value of acceleration captured at the three sensor axis applying vector addition, using the software DataAnalyzer[2]. With this step, gravitational components were excluded using a high-pass filter (0.25 Hz), and artifacts (such as shocks to the device from driving by car) were excluded using a low-pass filter (11 Hz).

Second, we combined the e-diary data and the 1-min intervals of Movement Acceleration Intensity [milli-g] using the software DataMerger (version 1.6.3868)[2]. Based on former studies (e.g., Bossmann et al., 2013; Kanning, 2013; Kanning et al., 2015), we parameterized non-exercise activity (such as walking to the supermarket, being physically active at work, etc.) as the aggregated mean Movement Acceleration Intensity [milli-g] across 10-min time frames.

Third, we used SPSS (IBM; version 23.0.0.0) to aggregate mean Movement Acceleration Intensity [milli-g] for the 10-min intervals directly following each e-diary entry (later referred to as [0–10]). Because we were also interested in the time course of effects of mood dimensions on non-exercise activity, we aggregated mean Movement Acceleration Intensity [milli-g] within consecutive 10-min intervals following each e-diary entry. Specifically, we aggregated mean Movement Acceleration Intensity [milli-g] for the time frames from 11–20, 21–30, ..., up to 281–290, and 291–300 min (later referred to as [11–20], [21–30], etc.). Moreover, to focus our analyses on non-exercise activity and to thus not take exercise (such as jogging, playing tennis, etc.) into account, we excluded e-diary-assessments that were collected within 300 min prior to participants' exercises for all analyses. Additionally, because the distribution of non-exercise activity showed only few very high values and was right-skewed (due to a high amount of the participants' sedentary time), we log-transformed all outcome variables for the purposes of statistical analyses. Specifically, all computed values for the intervals of non-exercise activity ([0–10], [11–20], [21–30],..., up to [291–300]) were log-transformed applying the natural logarithm.

Thereafter, we conducted multilevel analyses to investigate within-person influences of mood dimensions (i.e., valence, energetic arousal and calmness) on non-exercise activity using SPSS (version 23.0.0.0., IBM). We nested repeated measurements (level 1) within participants (level 2) and calculated unconditional models to estimate intra-class correlations. Next, we calculated our main model using the outcome variable non-exercise activity, which was defined as the mean Movement Acceleration Intensity (logarithmized values) over the 10-min interval directly following the mood assessments. We included the level 1 predictors time, time-squared, valence within-subject, energetic arousal within-subject, and calmness within-subject. The predictors valence within-subject, energetic arousal within-subject, and calmness within-subject were centered around the persons' mean mood scores across the study week. The predictors time and time-squared were transformed to the daily study start time, i.e., we subtracted the value 7.5 because the study started at 7:30. To control for between-person effects, we added the level 2 predictors age, gender, BMI [kg/m^2], and exercise/week [min]. Additionally, we added the mean mood scores for each participant as a level 2 predictor, namely the between-subject values for valence, energetic-arousal, and calmness. Specifically, these predictors were calculated by aggregating the mean mood scores across all e-diary assessments for the whole study week for each participant. We successively added random effects for each level 1 predictor. However, we retained only significant random effects in the final model (refer to **Table 1**). Finally, to investigate the short- and long-term impacts of mood on non-exercise activity, we calculated 30 multilevel models changing the outcome variable (refer to **Figure 1**). In detail, we used the aggregated mean Movement Acceleration Intensity (logarithmized values) across time frames [0–10], [11–20], [21–30], ..., up to [291–300]. However, due to the results of our main model, we added only the level 2 predictors age, valence between-subject, energetic arousal between-subject, and calmness between-subject; we did not consider any random effects in these 30 models. We set the α-level to 0.05 for all the analyses.

Main Model

Level 1 equation:

$$\begin{aligned} Y_{ij} = {} & \beta_{0j} + \beta_{1j} \times \text{Time}_{ij} + \beta_{2j} \times \text{Time}^2_{ij} + \beta_{3j} \times \text{Valence}_{ij} + \beta_{4j} \\ & \times \text{Energetic Arousal}_{ij} + \beta_{5j} \times \text{Calmness}_{ij} + r_{ij} \end{aligned}$$

Level 2 equation:

$$\begin{aligned} \beta_{0j} &= \gamma_{00} + \gamma_{01} \times \text{Age}_j + \gamma_{02} \times \text{Gender}_j + \gamma_{03} \times \text{BMI}_j \\ &\quad + \gamma_{04} \times \text{Exercise}_j + \gamma_{05} \times \text{Valence}_j + \gamma_{06} \\ &\quad \times \text{Energetic Arousal}_j + \gamma_{07} \times \text{Calmness}_j + u_{0j} \\ \beta_{1j} &= \gamma_{10} \\ \beta_{2j} &= \gamma_{20} \\ \beta_{3j} &= \gamma_{30} \\ \beta_{4j} &= \gamma_{40} + u_{4j} \\ \beta_{5j} &= \gamma_{50} + u_{5j} \end{aligned}$$

The effects within subjects were estimated at level 1. The subscript j refers to participant j and subscript i to the time of measurement. The level of non-exercise activity at time i in participant j is represented by Y_{ij}. The intercept and the effects of time, time-squared, valence within-subject, energetic arousal within-subject, and calmness within-subject are represented by the beta coefficients (β) at level 1. The residuals are represented by r_{ij}. The between-subject effects were estimated at level 2.

TABLE 1 | Multilevel model analysis of influences of mood dimensions on non-exercise activity: Fixed and random effects.

Outcome	Fixed				Random			
Predictor	Beta coefficient	Standard Error	*t*-Value (df)	*p*-Value	Variance estimate	*SD*	Wald-Z	*p*-value
Intercept	2.60744	0.48976	5.32 (87.3)	<0.001	0.10377	0.01901	5.46	<0.001
Time [hours]	0.23052	0.01347	17.12 (5726.1)	<0.001				
Time-squared [hours^2]	−0.01334	0.00087	−15.34 (5785.4)	<0.001				
Age [years]	−0.02416	0.01426	−1.69 (85.7)	0.094				
Gender	0.03948	0.08555	0.46 (85.9)	0.646				
BMI [kg/m^2]	0.00480	0.01061	0.45 (83.4)	0.652				
Exercise/week [min]	−0.00022	0.00028	−0.79 (89.6)	0.434				
Valence within-subject	0.00444	0.00131	3.38 (5412.1)	0.001				
Energetic arousal within-subject	0.01411	0.00099	14.21 (96.3)	<0.001	0.00003	0.00001	2.25	0.025
Calmness within-subject	−0.01023	0.00166	−6.16 (123.0)	<0.001	0.00010	0.00003	3.28	0.001
Valence between-subject	0.02026	0.00762	2.66 (88.2)	0.009				
Energetic arousal between-subject	−0.00063	0.00480	−0.13 (88.0)	0.896				
Calmness between-subject	−0.01380	0.00604	−2.29 (85.7)	0.025				

As stated above, we retained only significant random effects in our final model. Since we found significant random effects only for the predictors energetic arousal within-subject and calmness within-subject, u_{4j} and u_{5j} represent the variation of participants' individual slopes for the predictors energetic arousal within-subject and calmness within-subject around the respective overall mean slope (refer to **Table 1**).

Model for Analyses of Time Course

For the analyses on the short- and long-term impacts of mood on non-exercise activity (refer to **Figure 1**), we used the model presented below. We calculated 30 multilevel models, changing only the outcome variables. Specifically, we inserted the non-exercise activity within the time frames [0–10], [11–20], [21–30], ..., up to [291–300] min after each e-diary entry as the outcome variables.

Level 1 equation:

$$Y_{ij} = \beta_{0j} + \beta_{1j} \times \text{Time}_{ij} + \beta_{2j} \times \text{Time}_{ij}^2 + \beta_{3j} \times \text{Valence}_{ij} + \beta_{4j} \times \text{Energetic Arousal}_{ij} + \beta_{5j} \times \text{Calmness}_{ij} + r_{ij}$$

Level 2 equation:

$$\beta_{0j} = \gamma_{00} + \gamma_{01} \times \text{Age}_j + \gamma_{02} \times \text{Valence}_j + \gamma_{03} \times \text{Energetic Arousal}_j + \gamma_{04} \times \text{Calmness}_j + u_{0j}$$
$$\beta_{1j} = \gamma_{10}$$
$$\beta_{2j} = \gamma_{20}$$
$$\beta_{3j} = \gamma_{30}$$
$$\beta_{4j} = \gamma_{40}$$
$$\beta_{5j} = \gamma_{50}$$

To compute the percentage changes in non-exercise activity, we used the equation below.

$$\delta = (e^{\beta(valence,\ energetic\ arousal,\ or\ calmness)\times 10}) - 1) \times 100$$

Ethical Considerations

This study was approved by the ethics committee of the Medical Faculty Mannheim at the Ruprecht-Karls-University in Heidelberg. This study fulfilled the ethical guidelines for medical research according to the Declaration of Helsinki. Written and oral information regarding the study procedures were presented to all eligible participants before written informed consent was obtained. There was no surrogate consent procedure. All participants were free to withdraw from the study at any time.

RESULTS

Descriptive Statistics

The 93 participants completed 81.2% (SD = 14.3) of all e-diary prompts, i.e., on average 10 mood assessments/participant/day. To focus our analyses on the influences of mood on non-exercise activity, we excluded 9.2% of the completed e-diary entries that were followed by exercise within 300 min; the final data set consisted of a total of 5980 mood assessments. Participants' average non-exercise activity was 36.3 milli-g/participant/minute (range = [14.3–58.6]; SD = 9.8) across the 7 assessment days. For the sake of comparison, sedentary behavior (e.g., sitting) is associated with approximately 7 mg, walking (3.1 mph gait speed) with approximately 367 mg, and jogging (6.5 mph gait speed) with approximately 1103 mg (Anastasopoulou et al., 2014). The mean mood scores of the whole sample were 71.2 (SD = 10.5) for valence, 57.9 (SD = 10.6) for energetic arousal, and 67.7 (SD = 11.5) for calmness. The within-subject correlations between the mood components calculated applying Fisher's Z-transformation indicated that valence and energetic arousal were moderately associated (r = 0.36) across the study week. Moreover, valence and calmness were highly synchronized (r = 0.66) whereas energetic arousal and calmness were scarcely correlated (r = 0.08) within persons. Non-exercise activity was defined as the mean physical activity occurring in the 10-min intervals directly following the e-diary assessments. The intra-class correlation

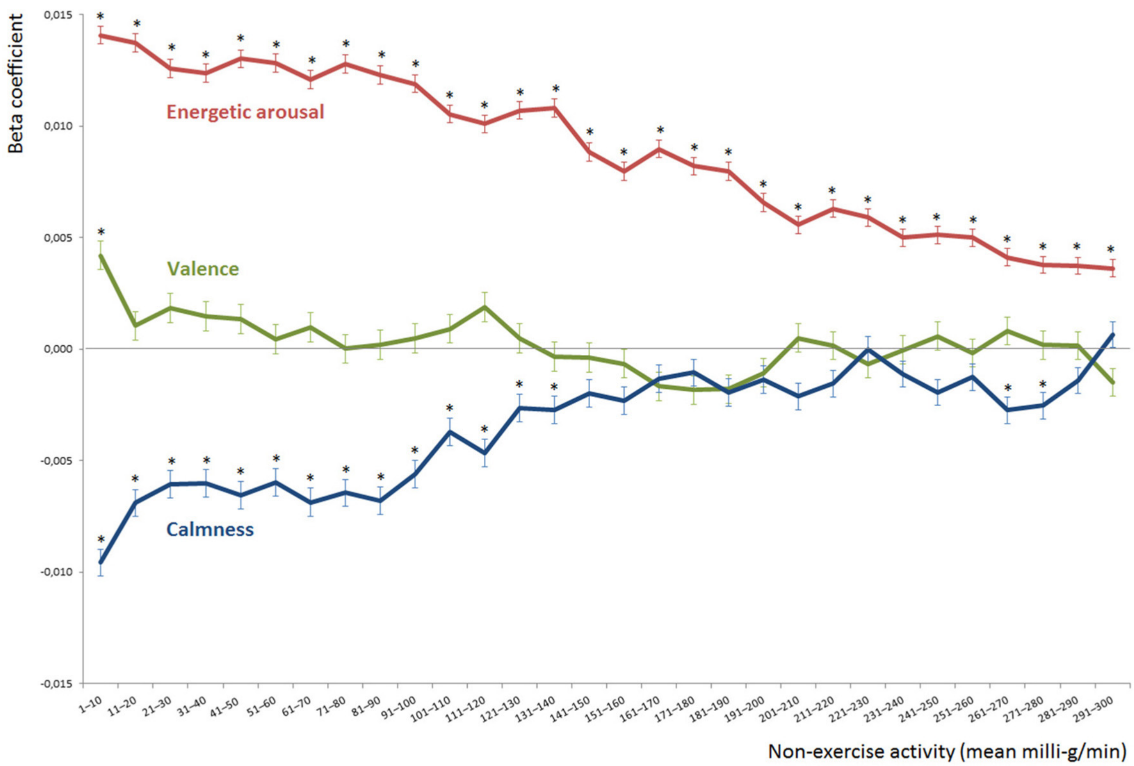

FIGURE 1 | Within-subject effects of mood dimensions on consecutive 10-min intervals of non-exercise activity. The y-axis shows the beta coefficients for valence, energetic arousal and calmness predicting the non-exercise activity occurring in the consecutive 10-min intervals after the e-diary prompts. The 10-min intervals of non-exercise activity are displayed on the x-axis, e.g., the axis label [41–50] refers to the mean non-exercise activity from minute 41 up to minute 50 after the e-diary prompts. * show significant effects of valence, energetic arousal and calmness predicting 10-min intervals of non-exercise activity ($p \leq 0.05$).

coefficient ($\rho_I = 0.068$) revealed that 93.2% of the variance was explained by within-subject variation in non-exercise activity. A total of 49 participants (52.7%) engaged in exercise, with an average exercise duration of 186.2 min/participant/week (*SD* = 137.8).

Predicting Non-exercise Activity

Table 1 shows the influences of various within-person (level 1) and between-person (level 2) predictors on non-exercise activity. Non-exercise activity was parameterized into 10-min intervals of physical activity following each e-diary prompt. Descriptively, seven of twelve predictors showed significance, namely time ($p < 0.001$), time-squared ($p < 0.001$), valence within-subject ($p = 0.001$), energetic arousal within-subject ($p < 0.001$), calmness within-subject ($p < 0.001$), valence between subject ($p = 0.009$), and calmness between-subject ($p = 0.025$). Age, gender, BMI, energetic arousal between-subject, and exercise/week lacked significance, i.e., were not associated with non-exercise activity.

As expected, we found significant influences of the three mood dimensions on non-exercise activity within persons. Specifically, valence was positively related to the 10-min episodes of non-exercise activity following each e-diary assessment within-persons (refer to **Table 1**), thus confirming hypothesis I. However, the small beta coefficient (0.004) indicated a minor influence of valence on non-exercise activity. In practice, a 10-point increase in valence (on a scale from 0 to 100) led to an average increase in non-exercise activity of 4.5% within the 10 min after an e-diary assessment. Regarding the mood dimension of energetic arousal, we again found a significant positive influence on non-exercise activity (refer to **Table 1**), thus confirming hypothesis II. The beta coefficient of energetic arousal (0.014) was much higher than that of valence. In practice, when participants felt 10 points more energized (on a scale from 0 to 100), their non-exercise activity increased on average by 15.2% over the 10-min interval post-e-diary prompt.

As hypothesized (hypothesis III), calmness was also significantly related to non-exercise activity (refer to **Table 1**). The negative beta coefficient (−0.010) indicated that the calmer participants felt, the lower their subsequent non-exercise activity was. In practice, when participants felt 10 points (scale of 0 to 100) more calm, their non-exercise activity decreased on average by 9.7% in the 10 min after each e-diary prompt. We found significant random effects only for the within-subject predictors energetic arousal and calmness (refer to **Table 1**). This finding indicated between-subject variability in the within-subject relationship between mood dimensions and non-exercise activity. However, the variance estimates were minor (refer to **Table 1**), indicating negligible differences.

Moreover, our model showed that the participants' non-exercise activity was significantly influenced by the time of day, with positive effects of time (beta coefficient = 0.231) and negative effects of time-squared (beta coefficient = −0.013; refer to **Table 1**). Specifically, the effects of time on non-exercise activity were reversely u-shaped, i.e., non-exercise activity increased from the daily study start time (at approximately 7:30) to the afternoon (approximately 16:00) and then decreased until the study end time (at approximately 22:30). Additionally, we found significant between-person effects of valence and calmness on non-exercise activity (refer to **Table 1**). Participants who felt better on average across the study week showed on average higher non-exercise activity within the 10-min intervals following the e-diary assessments (beta coefficient = 0.020). Participants with heightened feelings of calmness throughout the study week revealed on average lower levels of non-exercise activity (beta coefficient = −0.014; refer to **Table 1**). The finding that participants' mean levels of valence and calmness across the study week were related to non-exercise activity was consistent with intervention studies showing positive between-subject effects of exercise on positive affect (for an overview refer to Reed and Ones, 2006; Reed and Buck, 2009). However, due to their between-subject designs, these studies did not investigate how physical activity and mood increased and decreased within people over time, i.e., they provided no evidence regarding whether there was a timely relationship between episodes of physical activity and mood within persons.

Within-Subject Associations between Mood Dimensions and Non-exercise Activity over Time

To obtain a deeper understanding of the short- and long-term impacts of mood on physical activity, we analyzed consecutive time frames of non-exercise activity to determine the effects of mood dimensions. Determination of these effects was previously requested by Schwerdtfeger et al. (2010), but the effects remained largely unknown due to the methodological limitations of former studies (Liao et al., 2015). Therefore, we conducted several multilevel-analyses using models that were similar to our full model presented above (refer to **Table 1**) and inserted consecutive 10-min time frames of non-exercise activity following the e-diary assessments as the outcome variable (11–20, 21–30, ..., up to 281–290 and 291–300 min after e-diary assessment, later referred to as [11–20], [21–30], etc.). However, we excluded non-significant predictors (i.e., gender, BMI, exercise/week) and negligible random variables (i.e., within-subject energetic arousal and within-subject calmness) from the initial model. **Figure 1** shows the influence of valence, energetic arousal and calmness on the consecutive 10-min intervals of average non-exercise activity after each e-diary prompt. Specifically, the y-axis depicts the beta coefficients of the mood dimensions influencing the respective 10-min interval of non-exercise activity, which is displayed on the x-axis. For example, the value of the red line on the y-axis for the time frame from [31–40] min reveals the direction (positive) and magnitude (beta coefficient = 0.012) of energetic arousal influencing non-exercise activity.

Figure 1 shows a significant influence of valence on non-exercise activity only within the [1–10] min following e-diary assessments (beta coefficient = 0.004; p = 0.001). However, across all averaged time frames thereafter, we found non-significant beta coefficients, with values close to zero (green line). Moreover, our models revealed significant effects of energetic arousal on non-exercise activity across all time frames up to 300 min, illustrated with the red line (refer to **Figure 1**). The beta coefficients depicting the influence of energetic arousal on non-exercise activity generally decreased from the time frame [1–10] (beta coefficient = 0.014; $p < 0.001$) to the time frame [291–300] (beta coefficient = 0.004; $p < 0.001$). Thus, the effects of energetic arousal were highest within the first 10-min interval directly following the e-diary prompts and then continuously decreased up to 300 min after the mood assessments. The fact that the beta coefficients approached zero was not surprising and demonstrates how the effects subsided over time. The significant beta coefficients with values noticeably larger than zero for all time frames up to 300 min fits nicely with our finding of a large influence of energetic arousal on non-exercise activity as determined in the main model (refer to Section Predicting Non-exercise Activity). Additionally, the mood dimension calmness again showed the greatest influence on the first 10-min interval directly following the mood assessment (beta coefficient = −0.010; $p < 0.001$). The following beta coefficients decreased up to 300 min after the e-diary prompts. The significant and noticeably non-zero beta coefficients up to the time frame of [131–140] min (beta coefficient = −0.003; p = 0.026) again fit nicely with our finding that calmness negatively influenced non-exercise activity (refer to Section Predicting Non-exercise Activity).

DISCUSSION

As expected, our analyses showed significant within-person influences of mood dimensions on non-exercise activity, yielding distinct sizes and directions of effects for valence, energetic arousal and calmness. Specifically, valence was positively related to non-exercise activity within persons in the 10 min following a particular mood assessment, thus confirming hypothesis I. However, the effect of valence on non-exercise activity was small and the analyses of the other 10-min intervals of non-exercise activity up to 300 min after the mood assessments revealed non-significant effects close to zero. At first sight, this is surprising because three of six existing studies on within-person effects of mood on physical activity found positive affect to significantly influence subsequent physical activity (Liao et al., 2015). However, a closer look at these studies revealed that their results were limited regarding the influence of valence on non-exercise activity. In particular, Carels et al. (2007) were interested in predicting the initiation of self-reported bouts of exercise in obese adults throughout the day by morning mood, and Dunton et al. (2009) investigated a sample of adults

($n = 23$) aged above 50 years and also used self-reported levels of physical activity. Accordingly, both studies examined particular samples using self-reported physical activity, which is known to be only weakly related with objective measures of physical activity (Prince et al., 2008; Adamo et al., 2009). Moreover, Carels et al.'s (2007) study reported on exercise instead of non-exercise activity. Schwerdtfeger et al. (2010) found positive influences of positive affect on physical activity over 12 h using accelerometry in a large sample ($n = 126$). However, they assessed mood using the construct positive activated affect and thus did not differentiate between the mood dimensions valence and energetic arousal. Interestingly, Wichers et al. (2012), who investigated the effects of positive affect on physical activity in a large twin sample ($n = 504$), found weak evidence of positive affect decreasing physical activity. Moreover, only one of the five existing within-subject studies interested in the associations between negative affect and physical activity found significant influences of negative affect on subsequent physical activity, whereas the other studies were not able to show any association (Liao et al., 2015). Therefore, combining our findings with those of existing studies does suggest that valence is not necessarily a strong within-person predictor of non-exercise activity in adults.

As hypothesized (hypothesis II), energetic arousal significantly influenced non-exercise activity within persons. The beta coefficients indicated a strong effect of feeling energetic on non-exercise activity within the 10 min after e-diary assessments. Moreover, energetic arousal significantly influenced all 10-min intervals of non-exercise activity up to 300 min after the e-diary assessment, confirming a robust effect of energetic arousal on non-exercise activity. Our finding is consistent with Dunton et al. (2014), who found feeling less tired and more energetic to be related to subsequent physical activity in 119 children aged eleven to thirteen years. Moreover, Dunton et al. (2009) results indicated a non-significant trend of the effects of feelings of energy and fatigue on non-exercise activity. Schwerdtfeger et al. (2010) found mood, defined as positive activated affect, to positively influence physical activity within their sample. Accordingly, in their study, it remained unclear to which degree positive affect on the one hand and activation on the other hand accounted for this finding. Our results suggest that energetic arousal strongly increases non-exercise activity, whereas the effects of valence are small.

Because existing studies have treated mood as a two-dimensional construct, i.e., mostly investigating how positive and negative affect influence physical activity (Liao et al., 2015), the influence of calmness on physical activity has remained unclear to date. Our results showed significant negative within-person influences of calmness on the 10-min interval of non-exercise activity after mood assessment, thus confirming hypothesis III. In other words, when participants felt calmer, they were less physically active in everyday life. The time course analyses confirmed this finding, showing significant influences of calmness on non-exercise activity noticeably larger than zero for up to 130 min following the e-diary assessment.

LIMITATIONS

Several limitations of our study deserve mentioning. First, due to the accelerated longitudinal design of the URGENCY study with annual follow-ups, our sample consisted of adult participants aged between 18 and 28 years. Accordingly, our results are limited to this restricted age range. Second, as our sample comprised 62% female participants, the gender was unevenly distributed. However, we found no systematic differences in the results when checking for gender effects. Third, we focused our analyses on non-exercise activities (such as daily routines of walking to the office, climbing stairs) thus excluding exercise activities (such as swimming, playing football). Non-exercise activities are most often characterized by short activity duration and low activity intensity (Kanning et al., 2013). Since associations between mood states and physical activity may differ for physical activities with distinct duration and intensity, our results do not reveal, e.g., how mood states are associated with structured exercise activities characterized by high demands of energy consumption. However, as non-exercise activity has been shown to be an important determinant for human health (Healy et al., 2008; Wen et al., 2011), we made the conscious decisions to focus our analyses on non-exercise activity. Further research is needed to investigate within-subject associations between mood states and distinct subcomponents of physical activity. Fourth, as we found significant relationships between mood-dimensions and subsequent non-exercise activity, we interpreted that mood causes changes in non-exercise activity. This assumption of causality is based on the temporal order of mood assessments and examined time frames of non-exercise activity. However, the temporal offset of non-exercise activity relative to the mood ratings constitutes a causal criterion (Susser, 1991) but it does not evidence causality since other existing but hidden causal variables (or mechanisms) that influence both mood and NEA (e.g., circadian rhythms) may have been missed. Reininghaus et al. (2016) propose to conduct ecological momentary intervention studies to verify putative psychological mechanisms. They argue that this kind of approach is suitable to overcome uncertainties of solely investigating several causal criteria therewith reducing the likelihood to miss hidden causal variables. Thus, further studies are needed to evidence causality of mechanisms.

CONCLUSION

To the best of our knowledge, this is the first ambulatory assessment study on the topic of within-subject mood effects on non-exercise activity in a large community-based sample of adults over the course of 1 week using repeated real-time and real life assessments of mood, conceptualized as a three-dimensional construct, as well as objectively assessed non-exercise activity. In conclusion, we found differential influences of mood on non-exercise activity. Within participants, feelings of energy and tension strongly increased non-exercise activity in the time following the mood assessment. However, valence showed only small effects on subsequent non-exercise activity. Thus, ambulatory assessment approaches appear suitable to investigate the effects of mood on non-exercise activity. Our results increase the evidence for circular effects of mood and physical activity, thus yielding important insight into the mechanisms maintaining physical activity. These findings may contribute to fostering physically active lifestyles, which are known to be related to high health expectancy.

AUTHOR CONTRIBUTIONS

MR, HT, IR, HS, AZ, AM, and UE made substantial contributions to the conception and the design of the study. MR and HS acquired data. IR, MR, UE, HT, and AM analyzed and interpreted the data. MR, HT, IR, HS, AZ, AM, and UE were involved in drafting the manuscript and revising it critically for important intellectual content. MR, HT, IR, HS, AZ, AM, and UE have given final approval of this version of the manuscript to be published. MR, HT, IR, HS, AZ, AM, and UE agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of this work are appropriately investigated and resolved.

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Dropping Out or Keeping Up? Early-Dropouts, Late-Dropouts, and Maintainers Differ in Their Automatic Evaluations of Exercise Already before a 14-Week Exercise Course

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The aim of this study was to examine how automatic evaluations of exercising (AEE) varied according to adherence to an exercise program. Eighty-eight participants (24.98 years ± 6.88; 51.1% female) completed a Brief-Implicit Association Task assessing their AEE, positive and negative associations to exercising at the beginning of a 3-month exercise program. Attendance data were collected for all participants and used in a cluster analysis of adherence patterns. Three different adherence patterns (52 maintainers, 16 early dropouts, 20 late dropouts; 40.91% overall dropouts) were detected using cluster analyses. Participants from these three clusters differed significantly with regard to their positive and negative associations to exercising before the first course meeting ($\eta_p^2 = 0.07$). Discriminant function analyses revealed that positive associations to exercising was a particularly good discriminating factor. This is the first study to provide evidence of the differential impact of positive and negative associations on exercise behavior over the medium term. The findings contribute to theoretical understanding of evaluative processes from a dual-process perspective and may provide a basis for targeted interventions.

Keywords: exercise adherence, automatic evaluations, BIAT, dropout, associations, affect

INTRODUCTION

Automatic evaluations of exercising (AEE; i.e., the spontaneous associations of exercising with either positive or negative affect) are a fairly well-researched phenomenon (e.g., Bluemke et al., 2010; Antoniewicz and Brand, 2014). Engagement in exercise is not just a consequence of deliberate reasoning but also the result of unintentional, automatic evaluations. Most empirical research on AEE has focused on correlations between AEE and exercise volumes (Bluemke et al., 2010; Conroy et al., 2010), the predictive power of AEE in relation to proximal episodes of physical activity (e.g., step counts for 1 week, Conroy et al., 2010) or decisions about exercising (Antoniewicz and Brand, 2014; Brand and Schweizer, 2015). Other research has investigated changes in AEE (Markland et al., 2015; Antoniewicz and Brand, 2016); however, the potential role of AEE in exercise maintenance has not been researched before.

Non-adherence to exercise programs is a well documented phenomenon (e.g., Marcus et al., 2000). Dropout rates of approximately 50% after a couple months are not uncommon (Matsumoto and Takenaka, 2004). We think that research on the psychological variables that influence the behavioral decisions of maintainers and non-maintainers is crucial to designing and implementing successful exercise interventions.

This study aimed to address a significant research gap by (1) providing a theoretical account of the role of AEE in exercise adherence and (2) testing a hypothesis relating exercise adherence to AEE which was derived from this account.

The Role of Automatic Evaluations of Exercising in Exercise Maintenance

According to dual process models of social cognition evaluative reactions involve two interconnected evaluative processes: one spontaneous and automatic, the other rather thoughtful and deliberative (Chaiken and Trope, 1999; Kahneman and Frederick, 2002). The Reflective Impulsive Model (RIM; Strack and Deutsch, 2004) represents one attempt to explain the distinction. According to this model, an individual who comes to the conclusion that the advantages of exercising today (e.g., thinking about health benefits) outweigh the disadvantages (e.g., exercise is time-consuming) will develop an intention to exercise that evening. The RIM assigns this process to the reflective system. The model further assumes that at the same time as the reflective processing AEE (e.g., doing aerobics is enjoyable) arise as a result of activation of an associative network which is part of the impulsive system. These AEE elicit a corresponding motivational orientation (e.g., I want to attend an aerobic session today). This aspect of social cognition – the role of the impulsive system – is central to our study.

Automatic evaluations of exercising represent learnt associations, which serve as a "conceptual and procedural long-term memory, where associative weights between contents change slowly and gradually" (Deutsch and Strack, 2006, p. 167) and according to RIM the salience and accessibility of these associative clusters varies according to the frequency of their activation. One would expect a regular exerciser to have strong, easily accessible positive affective associations to exercising and weaker negative affective associations to exercising.

Exercising is massively associated with bodily sensations and evokes affective responses (Ekkekakis et al., 2011). Affective states provide information and can be registered in memory (Clore, 1992; Ekkekakis et al., 2016). External stimuli (e.g., the experience of entering the gym) and internal stimuli (e.g., thinking about exercising) can activate affective representations which serve as inputs to evaluative information processing. Findings from exercise psychology show that positive affect during and after exercise predicts future exercising (e.g., Ekkekakis et al., 2011), and that positive AEE, as well as unconnected evaluative judgments, influence immediate decisions about exercising (Brand and Schweizer, 2015). Repeated activation of stored affective representations by acute affective states, experienced during and shortly after exercise, reinforces their association with exercise (Deutsch and Strack, 2006), i.e., increases the strength of the association between mental representations of exercise behavior and affective evaluative concepts. Every time an individual has to decide whether or not to attend the exercise course that day, both reflective and impulsive evaluative processes contribute to the formation of a motivational orientation (in the impulsive system) and a behavioral intention (in the reflective system), and reinforce pre-existing affective representations associated with attending the exercise course. This learning cycle is the reason why we expected to find predominantly positive spontaneous AEE in persistent exercisers.

Researching Automatic Evaluations of Exercising

Individuals are often unaware of their automatic associations (Nosek et al., 2007) and data based on questionnaires that ask participants to introspect about such associations are therefore not an appropriate or valid measure of them, so over the past 20 years researchers have begun to investigate the validity of response time latency tasks (Fazio and Olson, 2003) as indicators of automatic associations. These indirect tests, e.g., the Affective Priming Task (Fazio et al., 1995) and the Implicit Association Test (IAT; Greenwald et al., 1998), infer the individuals' AEE from the speed with which they categorize word or picture stimuli into various categories.

The Implicit Association Test

Over the past two decades the IAT (Greenwald et al., 1998) has become recognized in social psychology as a standard measure of spontaneous associations between mental concepts (it should be noted, however, that there is active debate on the automaticity of the measured reactions; De Houwer et al., 2009). The standard version of the IAT uses sets of stimuli related to two complementary targets (e.g., 'exercise' vs. 'non-exercise') or two complementary evaluative categories ('good' vs. 'bad'). The respondent has to sort the stimuli as quickly and accurately as possible into combined categories which are varied systematically across blocks (e.g., stimuli representing 'exercise' or 'good' are moved to the left side whilst stimuli representing 'non-exercise' or 'bad' stimuli are moved to the right side in test block A; whereas in test block B 'exercise' and 'bad' stimuli have to be sorted to the left side and 'non-exercise' and 'good' stimuli are sorted to the right side). Research from exercise psychology indicates that there is no clear conceptual opposite of 'physical activity' (e.g., Rebar et al., 2015). The brief IAT (BIAT; Sriram and Greenwald, 2009) is a version of the IAT which addresses this issue. In the BIAT participants only have to pay attention to two out of four categories in each test block (i.e., detect whether stimuli represent the concepts of, e.g., 'exercise' or 'good' in one test block and 'exercise' or 'bad' in the other). This makes features of the non-focal category ('non-exercise') less important. Another approach to addressing the lack of a complement to the target category is the Single Category (SC)-IAT (Karpinski and Steinman, 2006). In one SC-IAT block respondents decide whether stimuli belong to the categories 'exercise' or 'good' *or* to the category 'bad'; in the other test block they decide whether stimuli belong to the 'exercise' or 'bad' categories *or* to the evaluative category 'good.'

The common assumption underlying all IATs is that when stimuli sharing the same response are compatible (e.g., for participants who evaluate exercising positively the same response is required to stimuli representing 'exercise' or 'good') stimuli are handled more quickly than when the categorization is incompatible with one's automatic evaluation. Test scores are usually calculated by subtracting mean reaction times from the incompatible block from those in the compatible block – the two associative foci (Sriram and Greenwald, 2009) – divided by the pooled standard deviation from blocks. The resulting relative difference score (*D*-score; Greenwald et al., 2003) is an effect size-like measure. Thinking of a continuum between either having spontaneous negative affective evaluations with exercising or positive affective evaluations, the *D*-scores resembles one score along this continuum. A positive *D*-score can be interpreted as relatively positive AEE.

Selected Relevant Studies

A few exercise psychology studies have already used IATs and the *D*-score to illustrate the relationships between automatic evaluations from various forms of physical activity (e.g., Conroy et al., 2010; Hyde et al., 2012; Antoniewicz and Brand, 2016).

Conroy et al. (2010) employed the SC-IAT to show that more positive *D*-scores (i.e., faster reactions to 'good' stimuli when the same response is required for stimuli belonging to the target category of exercise) were associated with higher physical activity (number of steps per day) after controlling for well-established predictors of physical activity (e.g., self-efficacy). The authors concluded that spontaneous physical activity behavior over a short timeframe - 1 week - was influenced by both reflective motivational processes and impulsive processes.

Hyde et al. (2012) used the same length of observation period, 1 week, and focused on the stability of participants' automatic evaluations. At the beginning and end of the 1-week period participants worked through a SC-IAT and reported their physical activity during the previous week. Changes in *D*-score indicating a shift to a more favorable AEE were accompanied by an increase in physical activity level. The authors concluded that AEE include stable and more temporally variable components, both of which are related to physical activity behavior.

Antoniewicz and Brand (2016) investigated variability in AEE by manipulating participants' AEE with an Evaluative Conditioning Task. They assessed changes in SC-IAT *D*-scores immediately after the manipulation in three experimental groups (associating exercise with positive affect; associating exercise with negative affect; control condition). The manipulation was shown to be effective; *D*-scores were significantly higher in the group that learned positive AEE than in the control group. Drawing on theories positing that the impulsive system is based on associative processes (Deutsch and Strack, 2006) and the proposed interpretation of *D*-scores (Greenwald et al., 2003) the authors distinguished between the two *D*-score components (i.e., associations between 'exercise-good' – the positive associative focus and 'exercise-bad' – the negative associative focus) and analyzed their manipulation induced changes. This revealed that the observed learning was mainly driven by changes during the 'exercise-bad' association rather than the 'exercise-good' association. The authors interpreted this as an indication that amongst their sports student participants the 'exercise-good' association was relatively stable, whilst the 'exercise-bad' association was more susceptible to manipulation.

This Study

This study aimed to address a significant research gap by investigating the influence of AEE on adherence to a long-term exercise program. We monitored participants' adherence to a 3-month program of exercise (classifying them according to adherence, e.g., dropouts vs. maintainers) and assessed their baseline spontaneous evaluative associations with exercise.

According to dual process theories such as the RIM, the motivational orientation toward exercise (e.g., approach or avoid exercise) is based on the difference between the weights of 'exercise-good' associations and 'exercise-bad' associations. There is no doubt that exercising can simultaneously have both positive and negative associations for an individual. Regular participation in an aerobics class might elicit positive affect when it evokes thoughts of the friends one meets there whilst also eliciting more negative affect related to the resulting muscle ache. It is our contention that although a relative measure such as BIAT *D*-score might reflect AEE and hence capture differences between exercisers and non-exercisers as shown before, the initially measured *D*-score might be too robust to reflect the more nuanced differences between people who start an exercise program and adhere (i.e., maintainers) and people who do the same and quit in the long run (i.e., dropouts). We assume that it could be useful to conceive AEE in terms of separate exercise-positive and exercise-negative associations rather than using combined measures (e.g., *D*-score).

Carrying forward findings from previous studies (Antoniewicz and Brand, 2016) we expected to find inter-individual differences not only between exercisers and non-exercisers but also between finer behavioral sub-groups (e.g., sporadic vs. frequent exercisers) on the level of the two more nuanced exercise-positive and exercise-negative associations. We hypothesized that at baseline (before the start of the exercise program) positive associations (i.e., a positive associative focus) would be stronger in participants who would subsequently persist with the program than in those who would drop out.

MATERIALS AND METHODS

Participants

Sample

Data were collected from 121 participants. Data from some participants were excluded from analysis because of problems understanding the instructions for the tests ($n = 20$), because participants had left the exercise program ahead of schedule for health reasons ($n = 2$), because they had an error rate of more than 20% in BIAT sorting trials ($n = 7$) or because they reported before the program that they had little intention of finishing the program ($n = 4$). Intention to finish the program was assessed with a single question, "How committed are you to completing the exercise course?," with answers given on a six-point Likert scale ranging from 0 = 'no intention at all' to 5 = 'very strong intention.' Intending to finish the program (score of at least 4) was a pre-defined inclusion criterion, thus reducing influences of the reflective system (i.e., intention) for adhering, while looking for differences in the impulsive system (i.e., AEE). Final analyses were based on data from 88 participants (24.98 years ± 6.88; 51.1% female).

Adherence Clusters

In order to minimize bias in the data due to socially desirable responding (Kristiansen and Harding, 1984) and recall bias, attendance at the 14 exercise sessions was documented by the exercise instructor (present coded as '1'; absent coded as '0') at the start of the session. Taking up the idea of Seelig and Fuchs (2011), we chose to refrain from the often used simple way of counting exercise sessions and calculating average participation rates and frequencies. Instead, we transformed our behavioral variable (whether a person is present or absent) to a categorical criterion measure and sought to identify typical adherence patterns. By doing so, we were able to depict behavioral qualities rather than artificial fractions of actually indivisible behavioral entities. Therefore the individual adherence data was transformed into 12 simple moving averages (each based on three sessions) per participant. The resulting series of moving averages were examined with hierarchical cluster analyses to identify different patterns of adherence in our group of participants. Three different adherence patterns emerged. Fifty-two participants were classified as 'maintainers,' 16 as 'early dropouts' and 20 as 'late dropouts' (giving an overall drop-out rate of 40.91% for the course). The results of this analysis and the chronology of adherence patterns are illustrated in **Figure 1**. Individuals of the maintainer group for example managed to at least reasonably adhere to the exercise program (78,85% attendance, range = 42.86–100.00%), whereas early dropouts stopped visiting the program during the first half of the 14-week exercise program (14.73% attendance, range = 7.14–35.71%) and late dropouts during the second half (56,01% attendance, range = 28.57–71.43%). The adherence groups did not differ with regard to age [$F(2,82) = 1.28$, $p > 0.05$]), gender [$\chi^2(2) = 1.31$, $p > 0.05$] or intention to participate in the course, $F(2,85) < 1$. Early dropouts ($M = 175.33$ min, $SD = 112.75$), late dropouts ($M = 160.00$ min, $SD = 95.59$) and maintainers ($M = 202.75$ mins, $SD = 119.75$) reported taking similar weekly volumes of exercise before the first course meeting [$F(2,83) = 1.13$, $p > 0.05$].

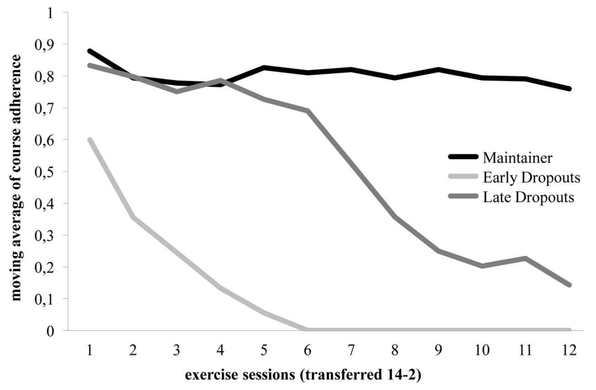

FIGURE 1 | Adherence groups with temporal development of course participation.

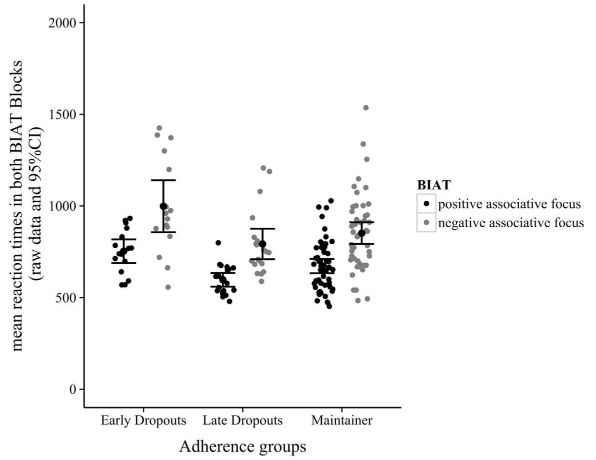

FIGURE 2 | Mean reaction times in both BIAT blocks.

Materials

Positive and Negative Associations

Automatic evaluations of exercising, positive and negative associations with exercise, were measured with a pictorial BIAT. The stimuli depicted scenes representing the target category 'exercise' (e.g., running, playing soccer, playing tennis, doing gymnastics) or non-sports activities (e.g., sleeping, watching TV, reading, sitting), i.e., the non-focal category. All stimuli were without obvious affective content (e.g., smiling faces). The evaluative categories 'good' and 'bad' were represented by eight (four and four) different smileys and frownies. Stimuli were presented in the middle of the screen and remained there until the participant categorized them by pressing the 'E' or 'I' key on a standard QWERTZ keyboard. In test block A (positive associative focus) participants had to press the 'E' key if the stimulus belonged to either the target category 'exercise' or the evaluative category 'good'; they were asked to press the 'I' key in response to all other stimuli in this block. In test block B (negative associative focus) 'exercise' and 'bad' stimuli were assigned to the 'E' key and all others to the 'I' key. Block order was counterbalanced between participants. All participants started with 24 practice trials, followed by 40 trials with response time logging (Inquisit 2.0 software). They were instructed to categorize stimuli as quickly and accurately as possible. The resulting *D*-score was calculated with the revised scoring algorithm by Greenwald et al. (2003).

Design and Procedure

Before the first exercise session potential participants were asked whether they were willing to take part in a study on 'evaluations of exercising.' Participants completed their first BIAT immediately before the start of the first exercise session. Then they completed a short paper–pencil questionnaire containing questions on intention of finishing the exercise course, weekly volume of exercise (in minutes per week) and basic socio-demographic information (age and gender). Finally, the course instructors documented the presence or absence of participants. Attendance was documented by instructors before each session throughout the 14 weeks of the exercise course. The participants attended a weekly exercise course that combined cardio training with exercises focusing on strength and coordination. Participants were fully debriefed, after the last exercise session. The study was carried out according to the recommendations of the ethical committee of the University of Potsdam.

Statistical Analyses

Group differences in *D*-scores were assessed using one-way analysis of variance (ANOVA) and group differences in the separate positive and negative associative foci were analyzed with one-way multivariate analysis of variance (MANOVA) with the associative foci as dependent variables and the adherence groups as independent variables. Follow-up discrimination analysis (Field, 2013) was used as a *post hoc* test. This strategy allows to analyze the relative discriminative power for each of the two (inter)dependent variables 'positive and negative associative foci' with regard to the criterion variable adherence group (maintainer; early dropout; late dropout).

RESULTS

Full descriptive data are given in **Table 1**. ANOVA revealed that *D*-scores were similar for the three groups, $F(2,85) = 0.57$, $p > 0.05$, with early dropouts having the least positive AEE (*D*-score = 0.40). However, in the MANOVA there was an omnibus effect (Pillai's trace) of adherence group on positive and negative exercise associations (**Figure 2**), $V = 0.15$, $F(4,170) = 3.35$, $p < 0.01$, $\eta_p^2 = 0.07$. A follow-up discriminant function analysis revealed two functions, explaining 99.6% (canonical $R^2 = 0.16$) and 0.4% (canonical $R^2 < 0.01$) of the variance, respectively. The combination of the two discriminant functions differentiated between the three groups, $L = 0.85$, $\chi^2(4) = 13.33$, $p < 0.01$. Removing the first function revealed that the second function did not contribute significantly to the effect, $L = 0.99$, $\chi^2(1) = 0.52$, $p > 0.05$. Inspection of correlations between the independent variables and the two discriminant functions revealed that positive exercise associations were strongly positively loaded on the first function ($r = 0.97$) and weakly to moderately negatively loaded on the second function ($r = -0.21$); negative exercise associations were strongly positively loaded on the second function ($r = 0.84$) and less strongly positively loaded on the first function ($r = 0.55$). These results suggest that the two associative foci are differently associated with the adherence groups.

TABLE 1 | Means and standard deviations of the dependent variables for the three adherence groups.

Dependent variables	Early dropouts	Late dropouts	Maintainers
Positive associative focus	753.43	597.28	671.89
	(120.83)	(79.93)	(139.80)
Negative associative focus	998.37	792.67	905.11
	(266.10)	(178.13)	(339.95)
D-score	0.40	0.55	0.52
	(0.47)	(0.28)	(0.51)
Intention	4.88	4.85	4.77
	(0.34)	(0.37)	(0.40)

Values in braces are the standard deviations of the adherence groups mean reaction times, D-scores or intention measure.

DISCUSSION

The aim of this study was to examine individual differences in positive and negative associations with exercise in exercisers who started a 3-month program of weekly exercise sessions. Analysis of adherence to the program uncovered three groups of exercisers, maintainers, early dropouts and late dropouts. We detected no statistically significant differences on the level of average *D*-scores. However, the strengths of positive and negative associations with exercise measured before the start of the exercise program differed significantly and with a medium-sized effect between the three adherence groups. In order to better understand the differences between the two associative foci and the adherence groups, a discriminant function analysis was conducted. This approach is recommended, since MANOVA examines "whether groups differ along a linear combination of outcome variables and discriminant function analysis, unlike ANOVA, breaks down the linear combination in more detail" (Field, 2013, p. 654).

Discriminant function analysis revealed that a combination of the two underlying types of exercise association (positive and negative) was highly effective in discriminating between the three adherence groups. Positive exercise associations contributed more to adherence group classification. The three groups were identified empirically (we described whether our participants were present or not) after our measurement of AEE; we thus conclude that AEE in the positive focus (not in the negative focus) are helpful in predicting exercise course adherence. Having a closer look at the positive associative focus, on the descriptive level, early dropouts seem to have the longest reaction times. This goes in line with our expectations. However, maintainers did not display the shortest reaction times (i.e., the most favorable exercise associations). There are several explanations for this result. First, the reliabilities of IATs are part of a lively debate (e.g., Banse et al., 2001) leading at least some researchers to the conclusion that indirect measures like the IAT should "be used with caution" (Bluemke and Friese, 2008, p. 977). The slightly faster reaction times of the late dropouts, compared to the maintainers, could be due to measurement error. A second explanation lies in our exclusive inspection of the automatic level, the two associative foci, while neglecting probable (well-evidenced) influences from the reflective system. An initial positive association with exercising seems to facilitate later exercise adherence, according to our results. Nonetheless, planning and coping skills remain important and might help exercisers to overcome negative automatic evaluations. Future studies are needed to focus on probable interactions between the impulsive and reflective components influencing exercise behavior.

Previous studies investigated the association between AEE and exercise behavior over a short time period (Conroy et al., 2010). Our findings extend understanding of the relationship between AEE and behavior in several ways. We suggest that adherence to a program of exercise can be described as a series of situated decisions of the form 'do I attend my aerobics class today or watch TV instead?' Earlier research has shown that AEE correlated significantly with situated decisions about exercising (Brand and Schweizer, 2015). Our data corroborate the hypothesis that long-term adherence to a program of exercise, i.e., repeated decisions to engage in exercise, and positive associations with exercising (associations between mental representations of 'exercise' and the evaluative category 'good') at the beginning of the course are correlated. This result is compatible with previous accounts of AEE and their role in physical activity behavior (e.g., Hyde et al., 2012).

In the terms of learning theory each exercise class represents a learning experience which influences the weights of associations between affective representations and exercise representations accordingly. A pre-existing positive AEE might act as a buffer against the effects of future exercise classes which might trigger predominantly negative affect. Deutsch and Strack (2006) posited that in long-term memory the weight of associations between, for example the concepts 'exercising' and 'good' change only slowly. If the stored evaluation of exercising is that it is 'enjoyable,' i.e., there is a stored association between exercising and positive affect which is reflected in a general motivation to engage in exercise, then it is likely that even if the individual has recently had an unpleasant (negative) experience of exercising his or her overall motivation to exercise will remain high (i.e., he or she is likely to make situated decisions to exercise, rather than undertake an alternative activity). This view is consistent with other authors' findings on the correlation between directly assessed hedonic responses to exercise and adherence to a program of exercise (Williams et al., 2008; Ekkekakis, 2009; Kwan and Bryan, 2010). Williams et al. (2008, p. 232) concluded that "a positive affective response may lead to greater participation in physical activity programs" on the basis of an assessment of affective responses to an exercise session and follow-up tracking of physical activity for 6 months. We propose that the correlation between positive affect and exercise behavior is not only a matter of reflective evaluative judgments based on rational deliberation (e.g., 'no pain, no gain') but also automatic evaluations (i.e., spontaneous affective responses or 'gut feeling'; the output of the impulsive system). This implies that exercise intervention practitioners should attempt to facilitate immediate, positive affective responses to exercise for participants in order to reinforce exercise-positive associations which may influence both impulsive and reflective processing of exercise-related stimuli and choices.

Our findings also contribute to understanding of AEE measurement. We suggest that it is more appropriate to conceive AEE in terms of separate exercise-positive and exercise-negative associations rather than as an overall AEE, on a single linear continuum. It is noteworthy that it is the overall linear continuum model which provides the rationale for calculation of IAT *D*-scores. Co-existing positive and negative associations and learning experiences in everyday life (e.g., exercising makes me feel better but at the same time it is time-consuming) are the norm rather than the exception. Our behavior is guided by this complex interplay of reflective judgments and automatic associations; both factors should be assessed in more detail when assessing patterns of complex behavior such as exercise habit. Assessing positive and negative associative foci separately supports a more nuanced interpretation of individual differences evaluations based on impulsive system processes. The lack of significant differences between the *D*-scores of maintainers and early and late dropouts reinforces the case for considering positive and negative automatic evaluations separately, particularly as differences between the adherence groups were detected when positive and negative associative foci were examined separately. Furthermore our results suggest that the positive and negative associative focus contribute differentially to patterns of exercise adherence. Given that we investigated individuals who already had decided to visit this exercise course it is unsurprising that most of them had positive associations involving exercise and that these positive associations had a significant impact on behavior. One would expect our participants to display strong or salient exercise-positive associations acquired as a result of numerous previous positive experiences of exercising (all opportunities for associative learning). As Strack and Deutsch (2006, p. 167) put it: "Frequently co-occurring perceptual features, valence, and behavioral programs form associative clusters, which vary in their accessibility according to the recency and frequency of their activation." Future research should investigate inactive individuals in order to clarify the observed differential impact of positive and negative associative in individuals without the intention to exercise.

CONCLUSION

We also conclude that our approach to describe exercise behavior on the full categorical level (i.e., visit the program or not) was successful. Many studies effectively described physical activities in terms of volume (e.g., step counts or minutes per week) and the observation that exercise volume correlates with AEE (e.g., Eves et al., 2007; Conroy et al., 2010) is certainly useful. This type of quantitative information neglected, however, qualitative behavioral differences, e.g., how similar volumes of exercise actually summed up. In a 14-week exercise session, individuals could either participate in every second exercise session (and thus be classified as a maintainer) or stop attending the exercise course after having been there for the first seven sessions (and thus belong to the late-dropout group). Accounting for such chronological information was fruitful and should stimulate further research and developments regarding the design of targeted exercise interventions (e.g., Keele-Smith and Leon, 2003).

Although the results of this study contributed to our understanding of AEE and their relationship with exercise behavior there are limitations to our study that need to be addressed. The moderate sample size of 88 participants needs to be mentioned. Since our study was embedded in an actual 14-week exercise program with uncertain attendance, we abstained from calculating an *a priori* power analysis. However, a *post hoc* analysis of the achieved power (taking our given sample and effect size into account) resulted in a power of 0.86, what supports the significance of our results. The regular exercisers in our sample all reported that they were likely to attend the sessions regularly and it is important to be cautious about generalizing the findings to less motivated individuals. The relationship between AEE and adherence to an exercise program in less motivated individuals is a question for future empirical research. It is also unclear whether the same results would have been obtained when investigating the relationship between AEE and exercise for more than 14 weeks.

These limitations notwithstanding, we think that our study highlights the influence of AEE and the two underlying associations on adherence to a program of exercise. Our aim was to enrich understanding of the research issues in several ways. First, we have offered a plausible theoretical account of the relationship between situations-specific AEE and long-term adherence to an exercise program. This invites further reflections on integrating AEE into theories of exercise behavior. Dual-system models are one approach to doing so and provide a basis for future research into exercise habits. Second, we have provided evidence that AEE predict exercise behavior over the long term, thus extending previous findings which investigated exercise habits or exercise behavior over short time periods. Third, the decomposition of AEE into its components (i.e., exercise-positive and exercise-negative associations) was shown to be essential to understanding the relationship between exercise behavior and AEE. Our finding improves understanding of the concept of AEE and should lead to development of more effective exercise interventions. Mainstream research in exercise psychology should investigate automatic as well as reflective processes of behavior regulation in the future.

AUTHOR CONTRIBUTIONS

FA developed this research question. FA conducted the empirical part of the study. RB and FA jointly re-analyzed the data, adjusted and broadened the chain of arguments and then cooperatively wrote this report.

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ORIGINAL RESEARCH
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Automatic Evaluation Stimuli – The Most Frequently Used Words to Describe Physical Activity and the Pleasantness of Physical Activity

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Physical activity is partially regulated by non-conscious processes including automatic evaluations – the spontaneous affective reactions we have to physical activity that lead us to approach or avoid physical activity opportunities. A sound understanding of which words best represent the concepts of *physical activity* and *pleasantness* (as associated with physical activity) is needed to improve the measurement of automatic evaluations and related constructs (e.g., automatic self-schemas, attentional biases). The first aim of this study was to establish population-level evidence of the most common word stimuli for *physical activity* and *pleasantness*. Given that response latency measures have been applied to assess automatic evaluations of physical activity and exercise, the second aim was to determine whether people use the same behavior and pleasant descriptors for *physical activity* and *exercise.* Australian adults ($N = 1{,}318$; 54.3% women; 48.9% aged 55 years or older) were randomly assigned to one of two groups, through a computer-generated 1:1 ratio allocation, to be asked to list either five behaviors and pleasant descriptors of *physical activity* ($n = 686$) or of *exercise* ($n = 632$). The words were independently coded twice as to whether they were novel words or the same as another (i.e., same stem or same meaning). Intercoder reliability varied between moderate and strong (agreement = 50.1 to 97.8%; $\kappa = 0.48$ to 0.82). A list of the 20 most common behavior and pleasantness words were established based on how many people reported them, weighted by the ranking (1–5) people gave them. The words people described as *physical activity* were mostly the same as those people used to describe *exercise*. The most common behavior words were 'walking,' 'running,' 'swimming,' 'bike riding,' and 'gardening'; and the most common pleasant descriptor words were ‘relaxing,’ ‘happiness,’ ‘enjoyment,’ ‘exhilarating,’ ‘exhausting,’ and ‘good.’ These sets of stimuli can be utilized as resources for response latency measurement tasks of automatic evaluations and for tools to enhance automatic evaluations of physical activity in evaluative conditioning tasks.

Keywords: dual process, implicit, non-conscious, modes, exercise

INTRODUCTION

Regular physical activity is essential for maintaining good physical and mental health (Warburton et al., 2006; Sattelmair et al., 2011; Rebar et al., 2015b); however, most people are not regularly physically active enough to obtain substantial health benefits (Bauman et al., 2009; Australian Bureau of Statistics, 2015). It is widely accepted that enhancing a person’s motivation can increase how active they are (Michie et al., 2009), but physical activity promotion efforts have narrowly targeted strategies meant to enhance reflective, intentional motivation such as self-monitoring and goal-setting at the expense of more non-conscious, impulsive predictors of behavior (Marteau et al., 2012; Sheeran et al., 2013). We can expand our knowledge of, and ability to promote, physical activity by focusing on the development of empirically sound tools for measuring and enhancing the non-conscious regulatory processes that also regulate physical activity behavior (Rebar et al., 2016).

Based on dual process theories, decisions to be active are the result, not only of reflective processes, which are slow and deliberate, but also non-conscious processes, which are rapid and spontaneous (Chaiken and Trope, 1999; Evans and Frankish, 2009). When opportunities to be physically active arrive, immediately (within 0.25 s!), we are biased to approach or avoid that opportunity depending on the non-conscious process referred to as ‘automatic evaluations’. *Automatic evaluations* are the immediate affective (i.e., pleasant/unpleasant) responses a person has toward an event or stimulus, which go on to influence decisions and behaviors (Murphy and Zajonc, 1993; Bargh et al., 1996; Cunningham et al., 2004). Although the exact origin of a person’s automatic evaluations is still unknown, it is suspected that they are an amalgamation of experiences with the event/stimulus and of the concepts and beliefs that they associate with it (Rudman, 2004; Cunningham et al., 2007).

Importantly, automatic evaluations may or may not be consistent with evaluations that a person reports about a behavior after some reflection. For example, a person could have somewhat unpleasant automatic evaluations of physical activity but self-report having strongly pleasant evaluations after some reflection. The exact interplay between non-conscious and reflective evaluations and their impact of physical activity behavior remains unclear, but evidence suggests that they are distinct (Hyde et al., 2010) and have distinct influences over a person’s physical activity behavior (Conroy et al., 2010).

People who automatically associate physical activity cues (e.g., words, images) with the concept of pleasantness are more physically active than people who do not have these associations – one study showed that 14% of physical activity behavior can be explained by these automatic evaluations (Rebar et al., 2015a). Automatic evaluations of physical activity have been assessed with a variety of response latency measures like the Implicit Association Test (Greenwald et al., 1998) or the Extrinsic Affective Simon Task (De Houwer, 2003). Although the procedures vary, the general aim of these tests is to gauge the degree of association people have between pleasantness/unpleasantness and the concept of *physical activity* based on timing and accuracy of responses to stimuli (e.g., words) that represent these concepts.

The validity of these response latency tasks is, in part, dependent on how well the stimuli represent the targeted constructs (i.e., *physical activity* and *pleasantness*). For example, Bluemke et al. (2010) showed that automatic evaluations were more linked to behavior when the *pleasant* stimuli were words describing positive experiences with physical activity (e.g., ‘athletic’), as opposed to just pleasantness in general (e.g., ‘patient’). Additionally, to be generalizable across a broad range of study samples, the stimuli should be words that most people in a population tend to associate with the targeted concepts. This study will be the first to provide population-level evidence about the words that most people perceive as representative of physical activity and exercise behaviors and of the pleasantness associated with physical activity/exercise.

In addition to providing stimuli for measures of automatic evaluations of physical activity, the findings of this study might act also as a resource for tools to enhance automatic evaluations of physical activity. For example, *evaluative conditioning* works to enhance people’s automatic evaluations through repeated presentation of stimuli representative of the targeted behavior alongside pleasant stimuli (Hofmann et al., 2010). This technique is commonly applied in advertising and political campaigns (e.g., pairing sexually appealing images with soda products, or constantly using negative words paired with opposing political candidate names) and used in interventions that have effectively changed other health behaviors including alcohol consumption (Houben et al., 2010) and healthy eating (Hollands et al., 2011). The findings of this study, therefore, will assist in the development of tools to promote physical activity via enhancement of automatic evaluations.

Although the discussion to this point has focused on physical activity, it is possible that researchers may also wish to investigate ‘exercise,’ as opposed to physical activity. Physical activity and exercise have similar but distinct meanings in the public health literature (Caspersen et al., 1985). In accordance with the research literature, *exercise* is a specific goal-directed type of *physical activity*; however, it is unclear whether the general population distinguishes between the terms 'physical activity' and 'exercise,' as many people use them interchangeably. This is an important unanswered question that has implications to consider for developing physical activity interventions including, but not exclusive to, strategies targeting automatic evaluations like evaluative conditioning. As such, the primary aim of this study was to establish a set of words that adults perceive as strongly representative of the concepts of *physical activity* and *pleasant*, and the secondary aim was to determine whether Australian adults differentiate between behavior and pleasant words to describe *exercise* versus *physical activity*. It is hypothesized that the differences are mainly within the academic community, so there will be few differences at the population level.

MATERIALS AND METHODS

Participants and Procedures

This study was a part of the 2015 National Social Survey – a population survey targeted at a random sample of Australian residents. Mobile and landline telephone numbers were dialed by a team of 34 interviewers via computer-assisted telephone interviewing by the Central Queensland University Population Research Laboratory in July – August of 2015. Gender-based and geographically proportionate random sampling of phone numbers was used to get near-equal sampling of men and women and to cover each state and territory area of Australia. Respondents were asked to participant in the study if they confirmed that they were 18 years of age or older. Participants ($N = 1{,}318$) were randomly assigned, in a ratio of 1:1 as determined by a computer-generated allocation, to answer the questions about either descriptors of 'physical activity' ($n = 686$) or 'exercise' ($n = 632$) behavior and pleasantness. A between-person design, as opposed to a within-person design in which the same participants were asked about 'exercise' and physical activity,' was used to reduce the risk of response biases. Asking people to report words relevant to the term 'physical activity' and then to the term 'exercise' (or vice versa) may have resulted in people feeling pressured to come up with different word choices, even if they did not perceive a true difference between the two terms.

Measures

A random half of the sample was asked, "Can you tell me five activities that you think about when you think of physical activity?" Interviewers clarified that, "We are looking specifically for behaviors, rather than feelings associated with physical activity." Next, these participants were asked, "Can you tell me five words that you would use to describe a physical activity that you enjoy or find pleasant?" At this point, interviewers clarified, "We are looking specifically for feelings, rather than behaviors associated with physical activity." The other half of the sample were asked the same questions about 'exercise' instead of 'physical activity.' Interviewers all used the same wording for each participant and recorded the participants' immediate responses in the order that participants reported them.

Data Coding and Analyses

Data were coded twice by independent reviewers (ALR, SS, SA) to assess (1) whether each response represented a novel 'word' category (*yes*/*no*), and (2) which 'word' category it represented (e.g., *aerobics, walking, calm,* and *competition*). Word categories represented responses with either the same stem (e.g., *walk* and *walking*) or the same meaning (e.g., *accomplishment* and *achievement*). There was no a priori determination as to what the 'word' categories would be or how many there would be. Interrater reliability was calculated as percentage agreement with a zero tolerance and unweighted Cohen's Kappa (κ; Gamer et al., 2012; Gwet, 2014), with $0.40 < \kappa < 0.59$ representing a weak level of agreement, $0.60 < \kappa < 0.79$ representing moderate agreement, and $\kappa \geq 0.80$ representing strong agreement (McHugh, 2012). Following the initial coding and reliability calculation, coding discrepancies were discussed amongst all three coders and the coding scores were adjusted accordingly to reflect the consensus code.

Scores were then calculated for each 'word' category as the number of participants that mentioned it, weighted by the ranking each participant gave it. The weighing was based on the assumption that people would report their most accessible or salient words first. Specifically, five points were given to a 'word' category for each time a person mentioned the 'word' first, four points for each mention as the second word, three points for each mention as the third word, two points for each mention as the fourth word, and one point for each mention as the fifth word. So, a score of 20 might represent a 'word' that four people mentioned as the first word representing the category or that 20 people mentioned as the fifth word representing the category. Based on the drop-offs of the distributions of the scores, it was determined that the top 20 ranked 'words' captured a reasonable sample of the most common responses.

RESULTS

The top 20 ranked words representing physical activity and exercise behaviors are presented in **Table 1** and the top 20 ranked words representing pleasant experiences of physical activity and exercise are presented in **Table 2**. Overall, there were not substantial differences between the words people used to describe physical activity and exercise.

Sample Characteristics

Response rate of the survey was 33%, which is typical for phone-based surveys (Curtin et al., 2000, 2005). There was a near equal sampling of gender ($n = 716$ women, 54.3%). Nearly half of participants were 55 years or older ($n = 645$, 48.9%), 16.6% ($n = 219$) were between the ages of 45–54 years, 14.1% ($n = 186$) were 35–44 years, and 19.3% ($n = 255$) were 18–34 years. A third of participants had education levels of secondary/high school or lower ($n = 436$, 33%), 22.2% had technical education or higher, and 44.2% ($n = 583$) had University or higher levels of education. In regards to employment status, 37.6% ($n = 496$) were employed full-time, 21.0% ($n = 276$) were employed part-time or casually, and the rest were unemployed

TABLE 1 | Rank ordering of the top 20 words people from independent samples used to describe physical activity or exercise behaviors and their associated representative scores.

Rank	Physical activity behavior words	Represen-tative scores	Exercise behavior words	Represen-tative scores
1	Walking	2027	Walking	1947
2	Running	1117	Running	1073
3	Swimming	795	Swimming	851
4	Gardening	763	Bike Riding	835
5	Bike riding	648	Gardening	440
6	Housework	482	Gym work outs	390
7	Gym work outs	451	Housework	301
8	Tennis	290	Tennis	279
9	Playing sport	282	Weight lifting	204
10	Manual labor	217	Playing sport	155
11	Golf	189	Golf	146
12	Football	186	Football	138
13	Weight lifting	150	Dancing	121
14	Yoga	116	Yoga	119
15	Dancing	115	Stretching	87
16	Farm work	110	Exercise machines	86
17	Chopping wood	98	Manual labor	85
18	Exercise	93	Exercise classes	84
19	Soccer	79	Playing with children	84
20	Hiking	73	Aerobics	78

TABLE 2 | Rank ordering of the top 20 words people from independent samples used to describe pleasant experiences of physical activity or exercise behaviors and their associated representative scores.

Rank	Pleasant physical activity words	Represen-tative scores	Pleasant exercise words	Represen-tative scores
1	Relaxing	836	Relaxing	713
2	Happiness	573	Happiness	509
3	Enjoyment	571	Exhilarating	412
4	Exhilarating	484	Exhaustion	379
5	Exhaustion	452	Good	353
6	Good	350	Enjoyment	308
7	Energetic	323	Fun	298
8	Fun	301	Social	271
9	Refreshing	287	Healthy	271
10	Satisfying	278	Energetic	250
11	Social	260	Calm	245
12	Achievement	246	Refreshing	235
13	Healthy	233	Satisfying	222
14	Calm	228	Achievement	212
15	Pleasant	211	Invigorating	204
16	Beautiful	176	Pleasant	177
17	Invigorating	147	Challenging	172
18	Challenging	137	Fit	170
19	Clarity	136	Beautiful	107
20	Painful	130	Free	100

($n = 61$, 4.6%), retired or pensioners ($n = 384$, 29.2%), students ($n = 35$, 2.7%) or responsible solely for home duties ($n = 57$, 4.3%).

Intercoder Reliability

Intercoder reliability ranged between moderate and strong. Reliability was highest for coding of whether or not each behavior word represented novel physical activity/exercise 'word' categories (physical activity behavior words: agreement = 95.9 to 97.8%; κ = 0.69 to 0.82; exercise behavior words: agreement = 96.4 to 97.3%; κ = 0.56 to 0.82). Reliability for whether or not each pleasant descriptor word was a novel 'word' category was acceptable (physical activity pleasant descriptors: agreement = 70.7 to 81.1%; κ = 0.70 to 0.79; exercise pleasant descriptors: agreement = 50.1 to 59.5%; κ = 0.47 to 0.53). Reliability for the 'word' categories of the physical activity/exercise behavior words remained within the strong/moderate range (physical activity behaviors: agreement = 79.6 to 89.8%; κ = 0.79 to 0.88; exercise behaviors: agreement = 77.7 to 82.8%; κ = 0.76 to 0.81). Reliability for the 'word' categories of the pleasant descriptors of physical activity/exercise was also within the acceptable range (physical activity pleasant descriptors: agreement = 70.8 to 81.2%; κ = 0.70 to 0.79; exercise pleasant descriptors: agreement = 50.1 to 64.6%; κ = 0.48 to 0.55). Lower reliability was commonly the result of one coding difference that occurred repeatedly amongst the most common answers.

Physical Activity and Exercise Behaviors

The most common word used to describe physical activity and exercise behavior was *walking*. Following in popularity were *running, swimming, bike riding,* and *gardening* for both physical activity and exercise. Of note, people reported leisure activities such as *golf*, *dancing*, and *yoga* as well as activities like *housework* and *manual labor* in their responses for both physical activity and exercise. The only major difference in the words people used to describe physical activity and exercise was that *exercise machines* and *exercise classes* were commonly reported to represent exercise, but few people responded that these behaviors represented physical activity (exercise representative scores: *exercise machines* = 86, *exercise classes* = 84; physical activity representative scores: *exercise machines* = 6, *exercise classes* = 17).

Pleasant Physical Activity and Exercise Descriptors

People described their pleasant experiences with physical activity and exercise similarly. People reported the words *relaxing*, *happiness*, *good*, *enjoyment, exhilarating*, and *exhaustion* as most representative. Some adjectives described mental states such as *clarity* and *energetic*, some focused on physical descriptors such as *healthy* and *fit*, and some focused on describing the activity such as *fun* and *challenging*. The words *clarity* and *painful* were reported as more representative as descriptors of physical activity (physical activity representative scores: *clarity* = 136, *painful* = 130) than of exercise (exercise representative scores: *clarity* = 72, *painful* = 74).

DISCUSSION

Researchers are beginning to measure and intervene with people's automatic evaluations of physical activity (Rebar et al., 2016). This study provides empirically based word stimuli representative of *physical activity/exercise* behaviors and *pleasant* descriptors of physical activity/exercise for use in such research. Not surprisingly, the most common words people used to describe physical activity behaviors were in line with findings of previous survey research on people's preferences for physical activities (Booth et al., 1997). The most common behavior words including transport (e.g., *walking*), leisure (e.g., *swimming*), and occupational (e.g., *manual labor*) activities. Almost all of the activities were aerobic. Generally, the stimuli used in previous studies of automatic evaluations of physical activity/exercise (e.g., Calitri et al., 2009; Scott et al., 2009; Conroy et al., 2010; Hyde et al., 2010; Rebar et al., 2015a) included more resistance-based (e.g., *lifting*, *sit-ups*) and fewer lifestyle (e.g., *gardening*, *manual labor*) behaviors than are present in the stimuli list from the present study. It may be that by not including certain types of physical activity in stimuli sets, these measures may not have fully captured automatic evaluations of the physical activity behaviors most relevant to certain individuals. Although the impact that the stimuli have on response latency measures is not clear, developers of such tasks suggest that the stimuli set should be well-representative and broad enough to encompass the entire targeted concept (De Houwer, 2001; Nosek et al., 2005). Researchers should consider incorporating stimuli that fully represent the relevant targeted behavior.

The pleasant descriptors of physical activity included pleasant-activated feelings (e.g., *exhilarating* and *energetic*) as well as pleasant-deactivated feelings (e.g., *relaxing* and *calming*). Some words described the instrumental value of physical activity (e.g., *healthy* and *fit*) and some words described more affective values (e.g., *fun* and *enjoyment*). This suggests people based their descriptions of pleasantness on both affective and instrumental attitudes, although evidence suggests that affective attitudes may be more predictive of physical activity behavior (Lowe et al., 2002; Rhodes et al., 2009). Most studies testing automatic evaluations of physical activity used generic positive/negative words and so were not similar to the stimuli produced from the present study (Calitri et al., 2009; Conroy et al., 2010; Hyde et al., 2010; Berry et al., 2011; Rebar et al., 2015a), but see Bluemke et al. (2010) and Brand and Schweizer (2015) for activity-based stimuli in German. The findings of Bluemke et al. (2010) suggest measures of automatic evaluations may be more linked to physical activity behavior if the adjective stimuli used are activity-related words; the outcomes of the present study make those types of stimuli more readily available for future researchers wishing to measure automatic evaluations.

There are a variety of measurement tools researchers can use to assess automatic evaluations including the Implicit Association Test (or variations thereof; Greenwald et al., 1998; Karpinski and Steinman, 2006; Siram and Greenwald, 2009), the evaluative priming method (Fazio et al., 1995; Eves et al., 2007), or the impulsive approach and avoidance manikin task (Krieglmeyer and Deutsch, 2010). The stimuli that emerged in this study can also be a resource for the assessment of other non-conscious constructs beyond automatic evaluations. For example, the list of physical activity or exercise words can be utilized when testing automatic associations between *physical activity/exercise* and *self* as a measure of non-conscious self-schema (e.g., Banting et al., 2009). Alternatively, the *physical activity/exercise* stimuli might be utilized in measures of attention biases such as via the dot probe task (e.g., Calitri et al., 2009). The present study list of stimuli will also likely be applicable for measures of self-reported affective and instrumental evaluations of physical activity.

Beyond measurement, these stimuli can be a resource for novel evaluative conditioning intervention tools that are integrated in broader health behavior interventions, as there has been a call to incorporate more strategies to target non-conscious regulation (Marteau et al., 2012; Sheeran et al., 2013). Evaluative conditioning has demonstrated long-lasting effects on behavior (De Houwer et al., 2001). Indeed, many people can attest to these long-term consequences when they have an automatic disgust response as a result of a long ago learned association of a particular food with nausea or when distant memories are provoked by a certain odor. Harnessing these long-term conditioning effects has potential for enhancing the effectiveness of physical activity interventions. Evaluative conditioning is only one strategy for intervening with automatic evaluations and other possibilities likely exist. For example, it may be that just by highlighted the positive attributes of physical activity in physical activity interventions (e.g., '*isn't this fun?,*' "*wasn't that relaxing?*"), people will be more likely to maintain regular activity because of the powerful motivational influence of recalling pleasant aspects of the experience (Kwan and Bryan, 2010). This study provides word stimuli resources to be used within such studies.

In addition to providing the stimuli list as a resources for future research, this study demonstrated that the words Australian adults use to describe *physical activity* are not substantially distinct from those used to describe *exercise*. This suggests that the distinction typically made in research that exercise is a goal-directed type of physical activity (Caspersen et al., 1985) may not be made by the general population. Some studies have focused on automatic evaluations of *physical activity* (e.g., Conroy et al., 2010; Hyde et al., 2012; Rebar et al., 2015a), whereas some have focused on *exercise* more specifically (e.g., Berry and Spence, 2009; Calitri et al., 2009; Bluemke et al., 2010). In light of the present findings, it may be the case that these measures of automatic evaluations of physical activity/exercise are targeting the same constructs. This finding points toward the possibility of summative work across these studies, although such efforts will be largely dependent on consistency of the behavioral measures.

Study Limitations

This study was designed to be representative of an Australian adult population. However, compared to the national population, the sample is older, on average (Australian Bureau of Statistics, 2013). As such, the findings cannot be generalized as being representative of all Australian adults. For example, the older population may explain why lifestyle activities were more commonly reported than resistance training activities. The set of words were meant to represent generic perceptions and are not tailored for specific population subsamples. Additionally, given that this study was conducted to obtain population-level evidence, all the behavior and pleasant descriptor words may not be applicable at an individual-level. Adjustments of the stimuli may be necessary for use in specific populations (e.g., men or women, specific age groups, people with specific chronic conditions). Alternatively, researchers may wish to design options for tailoring tests in an idiosyncratic fashion, so that the stimuli used are applicable for each person. Although the words seem broadly generalizable for English-speaking populations, this study sample was Australian and, therefore, the representativeness of the words may not be generalizable to people in other countries.

Another limitation is that the word stimuli lists were developed through self-reported methods, so might be more representative of deliberative, reflective evaluations and may not fully represent automatic evaluations. However, by asking participants to spontaneously report the words (without much deliberation), we have taken efforts to try and capture people's automatic responses. Additionally, although there was good intercoder reliability, by nature the coding of words as having similar meanings is a subjective task, and therefore, it cannot be ruled out that judgments made by the coders misrepresent the true meaning of the respondents on occasion.

Finally, although this study provides an important resource for use within response latency measures, the word lists produced may not meet all the stimuli needs of these measures, and therefore researchers may need to seek other resources to find other stimuli (e.g., general positive/negative word stimuli are available; see Bradley and Lang, 1999). Population-based evidence of negative descriptors of physical activity is not yet available; therefore researchers seeking to examine negative associations may need to conduct some pilot testing or base their stimuli on previously tested stimuli (e.g., Bluemke et al., 2010).

CONCLUSION

Automatic evaluations are underutilized in investigations of the psychology of physical activity and as a tool for increasing people's physical activity levels. This study provides population-level evidence-based sets of words that are highly representative of *physical activity/exercise* and *pleasant* descriptors of physical activity/exercise. These words can be used as a resource in efforts to better measure automatic evaluations in response latency tasks and to enhance automatic evaluations via evaluative conditioning tasks. The next step in this line of research is to find effective ways to utilize this resource to increase physical activity levels and stimulate the physical health benefits with which physical activity is associated (Warburton et al., 2006; Sattelmair et al., 2011; Rebar et al., 2015b).

AUTHOR CONTRIBUTIONS

AR, SS, SA, and CV helped conceive of the idea of the study design, assisted in coding, analyzing the data, interpreted the findings, and provided intellectual content for manuscript. CS, JD, BJ, DC, and RR helped conceive of the idea of the study design, assisted in interpreting the findings, and provided intellectual content for manuscript.

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