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Associations of Affective Responses During Free-Living Physical Activity and Future Physical Activity Levels: an Ecological Momentary Assessment Study

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Abstract

Purpose—Affective response during physical activity may influence motivation to perform future physical activity behavior. However, affective response during physical activity is often assessed under controlled laboratory conditions. The current study used ecological momentary assessment (EMA) to capture affective responses during free-living physical activity performed by adults, and determined whether these affective responses predict future moderate-to-vigorous physical activity (MVPA) levels after 6 and 12 months.

Method—At baseline, electronic EMA surveys were randomly prompted across 4 days asking about current activities and affective states (e.g., happy, stressed, energetic, tired). Affective response during physical activity was operationalized as the level of positive or negative affect reported when concurrent physical activity (e.g., exercise or sports) was also reported. Data were available for 82 adults. Future levels of moderate-to-vigorous physical activity (MVPA) were measured using accelerometers, worn for seven consecutive days at 6 and 12 months after the baseline assessment.

Results—Feeling more energetic during physical activity was associated with performing more minutes of daily MVPA after both 6 and 12 months. Feeling less negative affect during physical activity was associated with engaging in more daily MVPA minutes after 12 months only.

Conclusion—This study demonstrated how EMA can be used to capture affective responses during free-living physical activity. Results found that feelings more energetic and less negative during physical activity were associated with more future physical activity, suggesting that positive emotional benefits may reinforce behavior.

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Conflict of Interest The authors declare that they have no competing interests.

Compliance with Ethical Standards

Ethical Approval All procedures performed in the studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained from all the individual participants included in the study.

Keywords

Exercise adherence; Affect; Accelerometry; Free-living

Introduction

Given the significant health benefits of regular physical activity for both the general populations and at-risk individuals, physical activity promotion has become a priority for public health agencies throughout the world [1]. To aid in the design of effective physical activity interventions, a comprehensive understanding of the correlates and determinants of physical activity is critical. Research on this topic has mostly focused on cognitive factors, social factors, and environmental factors [2]. Although there are theoretical foundations for affective processes as determinants of adoption and maintenance of physical activity [3], only a few studies have examined this association empirically [4, 5]. Nevertheless, these studies measured change in affect before and after the exercise session, rather than *during* the exercise. Since affective states tend to rebound immediately post exercise, especially for high-intensity activities [6], some believe that affective state *during* physical activity rather than the pre-post affective change predicts physical activity adherence in the future [7].

Some recent studies have offered empirical support for the link between affective response during physical activity and overall physical activity participation [8, 9]. These studies demonstrate the potential for using affective response during physical activity as a predictor of future physical activity levels. Nevertheless, these studies captured physical activity-induced affective states in laboratory environments, which might differ from the ones individuals experience in their daily lives. Therefore, it is worthy to examine whether affective response during free-living physical activity also acts as a predictor of future physical activity levels.

Ecological momentary assessment (EMA) is a real-time self-report method to collect behavioral and cognitive processes as they are unfolding in naturalistic environments [10]. An advantage of the EMA method is that it can collect individual feelings in naturalistic settings when people are engaging in their daily physical activity. Although some studies have examined affective response to physical activity via EMA [11, 12], to date, no EMA study has examined the link between affective responses during physical activity and future physical activity levels. The current study aimed to address this important research gap by analyzing a longitudinal dataset with affective states measured via EMA and objective daily physical activity measured by accelerometer. It is hypothesized that more positive and less negative affective states during physical activity would be associated with higher future physical activity levels.

Methods

Participants and Procedures

This study used the longitudinal data from 82 participants in Project MOBILE, which included three waves of data, each separated by about 6 months [13]. Participants of Project

MOBILE were healthy adults ($n = 117$) living in and around Chino, California. Half of the participants ($n = 59$) were recruited through posters placed at community locations and letters sent to places of residence, and the other half of the participants ($n = 58$) were referrals from another larger research study. Inclusion criteria consisted of the following: (a) age of 28 years or older, (b) living in Chino, California, or a surrounding community, and (c) able to answer electronic EMA surveys while at work. Participants were excluded if they (a) did not speak and read fluently in English, (b) had an annual household income greater than \$210,000, (c) regularly performed more than 150 min per week of exercise or physical activity, or (d) had physical limitations making them unable to exercise. Individuals who met the eligibility criteria were scheduled for a data collection appointment at a local community site or their home. At each data collection wave, the participants were given a mobile phone that delivered randomly timed EMA survey questions up to eight times per day for four consecutive days, and wore an accelerometer during waking hours for seven consecutive days.

Measures

Affective Responses During Physical Activity—EMA data from the baseline were used in the current study. Each EMA survey sequence asked about participants' current activity, "What were you DOING right before the beep went off?". EMA responses with the choice of "Physical Activity/Exercise" or "Jogging/Running" indicated the participants were engaging in physical activity immediately prior to answering the EMA surveys. The participants were also asked about their affective states "just before the beep went off". To ensure the brevity of the EMA survey (i.e., each survey sequence can be finished in 1–2 min), selected affect items were chosen to be representative of the two fundamental dimensions of affect suggested by the circumplex model (i.e., valence and arousal) [14] and would capture affective response to physical activity [15, 16]. The positive affect scale included items that represent activated (happy, cheerful) and deactivated (calm or relaxed) pleasure (Cronbach's $\alpha = 0.84$). The negative affect scale included items that represent activated (anxious, stressed) and deactivated (depressed, angry) displeasure (Cronbach's $\alpha = 0.87$). In addition, there was one item assessing feeling of energy and one item assessing feeling of fatigue. Response choices for all the affect items were "1 = not at all, 2 = a little, 3 = moderately, 4 = quite a bit, 5 = extremely."

Physical Activity Level—Data from the accelerometer (Actigraph Model GT2M) were processed through MeterPlus (version 4.3). Consecutive zero activity counts for 60 min were marked as an invalid hour. Each participant needed to have at least four valid days (i.e., at least ten valid hours each day) in order to be considered as having valid accelerometer data at each wave. The MVPA cut-point for adults was 2020 activity counts per minute [17].

Data Availability

There were a total of 117 participants enrolled in Project MOBILE. At baseline, three participants' EMA data was mistakenly deleted prior to being downloaded, and therefore, EMA data was only available for 114 participants. Of these participants, 85 reported engaging in physical activity when answering the EMA surveys at least once across the four monitoring days. Three of the 85 participants did not have any affect assessments during

their physically active EMA prompts, and thus were not included in the analyses. In summary, a total of 82 participants indicated being physically active and answered affect questions across the baseline monitoring period. Therefore, these participants were our analytical sample. Among the 82 participants, 19 had more than two EMA entries for affective state questions during physical activity. Since majority of the participants only had one or two EMA entries for affective response during physical activity across the four monitoring days, average scores were created to indicate the positive and negative affective responses during physical activity.

Statistical Analysis

Difference scores were calculated to determine change in daily MVPA minutes from baseline to 6 months and baseline to 12 months. Linear regression analyses tested these change scores as the outcomes with average affective states during EMA-reported physical activity at baseline as the predictors. Each affective state was tested in a separate model. All models controlled for gender, age, ethnicity (Hispanic vs. non-Hispanic), weight category (normal weight, overweight, and obese), and average affective states during non-active prompts. Demographic and biological covariates were entered into the regression model in step one, and the affective predictors were entered into the regression model in step two. The demographic and biological covariates were chosen because they have been found to be correlated with daily physical activity levels in previous studies [18]. A significance level of $\alpha = 0.05$ was chosen to limit the probability of type I error at 5%.

Results

Descriptive Statistics

Of the 82 participants in the analytical sample, 73% were female, 31% were Hispanic, 67% were overweight or obese, and the mean age was 39.8 years. The excluded participants did not differ from the analytical sample in age, gender, race/ethnicity, or weight category. The participants on average had 1.83 (SD = 1.12) EMA entries for positive affect during physical activity, 1.85 (SD = 1.13) entries for negative affect, 1.83 (SD = 1.12) entries for energy, and 1.91 (SD = 1.21) entries for fatigue. On average, the self-reported positive affect during physical activity at baseline was 3.39 (SD = 0.63) on a 5-point scale, negative affect was 1.51 (SD = 0.72), energy was 3.37 (SD = 1.09), and fatigue was 1.63 (SD = 0.81). Average positive affect during non-active EMA prompts at baseline was 3.13 (SD = 0.64), negative affect was 1.42 (SD = 0.40), energy was 2.68 (SD = 0.67), and fatigue was 2.05 (SD = 0.62). The average daily MVPA minutes was 26.79 (SD = 22.32) at baseline ($N = 82$), 20.84 (SD = 11.90) at wave 2 ($N = 65$), and 22.21 (SD = 15.74) at wave 3 ($N = 64$). On average, the rate of change in MVPA minutes marginally decreased over time ($p = 0.06$). However, there was considerable variability between individuals in the size and direction of these changes, as shown by the $n = 18$ (40.0%) that increased MVPA between baseline and 6 months and the $n = 15$ (31.3%) that increased MVPA between baseline and 12 months.

Affective Responses During Physical Activity and Future Physical Activity Level

Tables 1 and 2 show the results from the linear regression models using change in MVPA minutes from baseline to 6 and 12 months as the outcomes and affective response during

physical activity at baseline as the predictor, respectively. Every 1-unit increase in feeling of energy during physical activity would lead to an increase of 4.62 min in MVPA per day after 6 months ($\beta = 4.62$, $SE = 2.00$, $p = 0.03$) and an increase of 5.24 min in MVPA per day after 12 months later ($\beta = 5.24$, $SE = 2.56$, $p = 0.04$), suggesting feeling more energetic during physical activity at baseline was associated with an increase in daily MVPA minutes after both 6 and 12 months. The hierarchical regressions indicated that feeling of energy accounted for 10% of the variation in changes in MVPA after 6 months and 9% of the variation in changes in MVPA after 12 months. Further, every 1-unit increase in negative affect during physical activity would lead to a decrease of 18.11 min in MVPA per day after 12 months ($\beta = -18.11$, $SE = 7.71$, $p = 0.02$), suggesting greater negative affect during physical activity at baseline was associated with a decrease in MVPA minutes after 12 months. Negative affect accounted for 5% of the variation in changes in MVPA after 12 months. Overall, the collinearity diagnostics for all models indicated little multicollinearity among the predictors and covariates (all condition indices <20).

Discussions

The current study used EMA to capture affective states experienced during free-living physical activity among inactive adults, and examined how these responses may influence future physical activity levels. Contrary to previous lab-based studies [8, 9], the current study did not find any association between the three items we used to represent positive affect (i.e., happy, cheerful, and calm/relaxed) during physical activity and change in daily MVPA minutes in 6 and 12 months later. It is possible that positive affective responses during physical activity differ between lab-based exercise tasks conducted for research purposes (e.g., treadmill task, cycle ergometer) and free-living exercise that takes place naturally in participants' everyday lives, or these responses differentially predict future engagement in physical activity. Nevertheless, due to our small sample size, one needs to interpret the results with caution. Further, results indicated that negative affect experienced during physical activity predicted a decrease in daily MVPA minutes after 12 months. Negative affect (e.g., angry, anxious) might occur during daily physical activity because of the type (e.g., competitive in nature) and/or duration of the activity. However, this study did not measure these aspects of the physical activity. Further, contextual environment (e.g., outdoor heat, crowded gym) might also contribute to some aspects of the negative affect. It is possible that the negative affective experience might decrease individuals' motivation in engaging in future physical activity. Future studies could explore some potential mediators (e.g., intrinsic motivation, cognitive factors) for the link between negative affective response to physical activity and physical activity maintenance.

This study also found that individuals who reported feeling more energetic during physical activity engaged in more MVPA in both 6 and 12 months later than individuals who reported feeling less energetic during physical activity. It is possible that individuals perceived feeling of more energy as one of the mental benefits from engaging in physical activity, and thus would be more likely to engage in physical activity in the future. This finding is consistent with results from previous cross-sectional studies that found a positive relationship between general feelings of energy and physical activity [19, 20].

Conclusions and Implications

The current study is among the first attempts to examine whether affective responses during physical activity in people's daily lives would predict future physical activity levels. It demonstrated that the use of electronic EMA via mobile phones could be a practical method to capture affective responses during free-living exercise among adults. The results from this study show that feelings of less negative and higher energy during free-living physical activity were positively associated with future physical activity levels. Since the participants of this study were inactive adults, the findings from this study could potentially offer some insights about how to promote physical activity in this particular population. For example, interventions could try to identify contextual factors that are associated with negative affective responses to physical activity (e.g., the activity is too intense, the environment is not comfortable, being indoors and alone) [21], and then offer strategies to overcome these factors (e.g., break activity into shorter bouts, try to exercise at a more pleasant location such as outdoor at a park). Future studies could further explore mechanisms that may explain the relationship between affective responses during physical activity and long-term physical activity maintenance.

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Results from linear regression model testing associations between affective response during physical activity and change in MVPA minutes in 6 months

Table 1

	Beta (SE)	Standardized coefficient	R ²	R ²	F
Step 1			0.17		1.82
Age	-0.16 (0.24)	-0.11			
Overweight	9.03 (5.74)	0.28			
Obese	7.30 (5.36)	0.24			
Hispanic	-8.93 (4.72)	-0.28			
Female	7.46 (4.75)	0.22			
Step 2					
Model 1 (N = 50)	N = 50		0.18	0.01	1.35
Age	-0.20 (0.25)	-0.13			
Overweight	8.62 (5.86)	0.27			
Obese	7.48 (5.64)	0.24			
Hispanic	-9.17 (4.88)	-0.29			
Female	6.77 (4.91)	0.20			
Positive affect during non-active EMA prompts	-1.07 (4.27)	-0.05			
Positive affect during active EMA prompts	2.45 (3.26)	0.14			
Model 2 (N = 49)			0.13	-0.04	0.84
Age	-0.26 (0.33)	-0.13			
Overweight	5.58 (7.73)	0.13			
Obese	-0.24 (7.84)	-0.01			
Hispanic	-7.77 (6.89)	-0.18			
Female	5.29 (6.92)	0.12			
Negative affect during non-active EMA prompts	15.35 (9.85)	0.34			
Negative affect during active EMA prompts	-11.86 (7.20)	-0.37			
Model 3 (N = 50)			0.27	0.10	2.20*
Age	-0.19 (0.23)	-0.13			
Overweight	7.25 (5.62)	0.23			
Obese	6.15 (5.43)	0.20			
Hispanic	-7.76 (4.60)	-0.24			

	Beta (SE)	Standardized coefficient	R ²	R ²	F
Female	6.16 (4.66)	0.19			
Energy during non-active EMA prompts	-1.69 (3.41)	-0.08			
Energy during active EMA prompts	4.62 (2.00) *	0.34			
Model 4 (N = 50)			0.05	-0.12	0.29
Age	-0.17 (0.37)	-0.08			
Overweight	8.05 (7.54)	0.19			
Obese	6.37 (7.56)	0.15			
Hispanic	-2.94 (6.83)	-0.07			
Female	3.78 (7.29)	0.08			
Fatigue during non-active EMA prompts	-3.66 (7.29)	-0.10			
Fatigue during active EMA prompts	1.89 (4.69)	0.08			

MVPA moderate-to-vigorous physical activity

* $p < 0.05$

Results from linear regression model testing associations between affective response during physical activity and change in MVPA minutes in 12 months

Table 2

	Beta (SE)	Standardized coefficient	R ²	R ²	F
Step 1			0.18		1.79
Age	0.06 (0.29)	0.03			
Overweight	6.82 (7.24)	0.17			
Obese	10.66 (6.73)	0.28			
Hispanic	-13.37 (6.01)*	-0.33			
Female	6.46 (6.03)	0.16			
Step 2					
Model 1 (N = 48)			0.19	0.01	1.31
Age	0.08 (0.32)	0.04			
Overweight	6.30 (7.40)	0.15			
Obese	9.49 (7.10)	0.25			
Hispanic	-12.72 (6.18)*	-0.32			
Female	6.61 (6.17)	0.16			
Positive affect during non-active EMA prompts	-3.84 (5.47)	-0.12			
Positive affect during active EMA prompts	2.28 (4.16)	0.10			
Model 2 (N = 48)			0.23	0.05	1.73
Age	-0.04 (0.33)	-0.02			
Overweight	2.70 (8.15)	0.06			
Obese	6.21 (8.03)	0.13			
Hispanic	-12.49 (7.16)	-0.27			
Female	3.40 (6.89)	0.07			
Negative affect during non-active EMA prompts	28.23 (10.20)*	0.57			
Negative affect during active EMA prompts	-18.11 (7.71)*	-0.51			
Model 3 (N = 48)			0.27	0.09	2.06
Age	0.10 (0.29)	0.05			
Overweight	4.28 (7.12)	0.10			
Obese	6.50 (6.89)	0.17			
Hispanic	-11.72 (5.88)*	-0.29			

	Beta (SE)	Standardized coefficient	R ²	R ²	F
Female	6.80 (5.87)	0.17			
Energy during non-active EMA prompts	-6.48 (4.58)	-0.22			
Energy during active EMA prompts	5.24 (2.56) *	0.30			
Model 4 (N = 49)			0.10	-0.08	0.68
Age	0.21 (0.38)	0.09			
Overweight	6.81 (8.21)	0.15			
Obese	10.99 (8.04)	0.24			
Hispanic	-8.97 (7.41)	-0.19			
Female	4.72 (7.59)	0.10			
Fatigue during non-active EMA prompts	-2.24 (7.56)	-0.06			
Fatigue during active EMA prompts	4.06 (5.09)	0.15			

MVPA moderate-to-vigorous physical activity

* $p < 0.05$