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Perceived Social Integration Predicts Future Physical Activity Through Positive Affect and Spontaneous Thoughts

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The present research evaluated the social, affective, and cognitive processes underlying sustained patterns of health behavior as articulated by the upward spiral theory of lifestyle change. Specifically, we tested whether positive affect experienced during physical activity changes over time in tandem with perceived social integration (PSI), and whether PSI is associated with future activity indirectly through sociality during physical activity, positive affect during physical activity, and positive spontaneous thoughts about physical activity. Adult participants (N = 226) reported daily on their PSI, physical activity behavior, and affect during physical activity for 11 weeks. Once every 2 weeks, they also reported on features of a specific bout of physical activity, including how social it was, positive affect during the activity, and positivity of spontaneous thoughts about physical activity. Multilevel modeling of daily reports over the 11 weeks revealed that as participants' PSI increased, so did their positive affect during physical activity. Further, structural equation modeling of specific reports revealed a significant indirect effect of PSI on future activity through sociality during an intervening instance of physical activity, positive affect experienced during that activity, and positive spontaneous thoughts about physical activity. The findings reported herein provide evidence consistent with the upward spiral theory of lifestyle change and reveal affective and cognitive mechanisms by which social processes may contribute to positive health behavior change and maintenance: namely, positive affect during physical activity and spontaneous thoughts about physical activity. Beyond its utility for evaluating theory, the present study may inform subsequent research aimed at developing sustainable behavior-change interventions.

Keywords: physical activity, perceived social integration, social interaction, emotions, spontaneous thoughts

Supplemental materials: http://dx.doi.org/10.1037/emo0000616.supp

Despite the well-documented benefits of physical activity for physical, psychological, and cognitive health, most Americans are insufficiently active (Centers for Disease Control and Prevention, 2016). Research has revealed that immediate barriers to being physically active, such as limited free time or expectations of aversive experiences, may inhibit activity even when people are aware of the future benefits to their health (Brownson, Baker, Housemann, Brennan, & Bacak, 2001; King et al., 2000). However, these barriers may be overcome by the promise of immediate rewards such as the enjoyment of exercise. Indeed, positive affect

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during physical activity has emerged as a compelling predictor of healthy lifestyle change, even among initially sedentary adults (Williams et al., 2008; Williams, Dunsiger, Jennings, & Marcus, 2012): It forecasts sustained physical activity as many as 12 months later (see also Rhodes & Kates, 2015; Woolley & Fishbach, 2016).

Prior research has identified a variety of factors that shape affective experiences during physical activity, ranging from exercise intensity (Ekkekakis, Parfitt, & Petruzzello, 2011) to genetic polymorphisms (Karoly, Stevens, Magnan, Harlaar, Hutchison, & Bryan, 2012). The social processes possible during physical activity may be additional candidates, given the documented potential for social connection to generate positive affect (e.g., Diener & Seligman, 2002; Kok et al., 2013; McIntyre, Watson, Clark, & Cross, 1991). Associations between social processes (e.g., social norms, social modeling, social support) and physical activity are particularly well established in the health behavior literature (e.g., Ball, Jeffery, Abbott, McNaughton, & Crawford, 2010; Sallis, Grossman, Pinski, Patterson, & Nader, 1987), potentially providing one lens through which to interpret the robust relationship between loneliness and mortality risk (Holt-Lunstad, Smith, & Layton, 2010). However, the effects of social processes on affective experiences during physical activity, and their aftereffects, are relatively uncharted. The purpose of the present research was to explore the dynamics and pathway by which social processes relate to physical activity via positive affect as articulated by the upward spiral theory of lifestyle change.

The Upward Spiral Theory of Lifestyle Change

The upward spiral theory of lifestyle change incorporates findings from distinct areas of affective science to specify the short-term and long-term processes by which positive affect contributes to sustainable behavior change (Fredrickson, 2013; Van Cappellen, Rice, Catalino, & Fredrickson, 2018). As illustrated in Figure 1, the model consists of two feedback loops. The inner loop suggests that positive affect experienced during healthy behaviors generates nonconscious motives for those behaviors, which, in turn, facilitate repeated behavioral engagement. This portion of the model is primarily informed by evidence for incentive-salience theory (Berridge, 2007; Smith, Berridge, & Aldridge, 2011), described below, which disentangles the distinct constructs of liking, incentive salience, and wanting.

Complementing earlier evidence from animal models (e.g., Cagniard, Balsam, Brunner, & Zhuang, 2006; Peciña, Cagniard, Berridge, Aldridge, & Zhuang, 2003), recent research in humans demonstrates how incentive salience operates as a nonconscious motive by rendering cues that are predictive of reward (given prior association with pleasant experiences) more likely to stand out to the perceiver (Ode, Winters, & Robinson, 2012). Other research invokes principles of automaticity to suggest that the heightened salience of cues predictive of reward generates positive spontaneous thoughts about the rewarding behavior, and those thoughts are, in turn, related to intentions to carry out the behavior (Rice & Fredrickson, 2017a, 2017b). In that work, experimentally manipulating the extent to which participants enjoyed an activity and subsequently measuring thoughts in real time revealed causal evidence for the effect of enjoyment on positive spontaneous thoughts (Rice & Fredrickson, 2017a; Study 2). In another study, participants who were led to believe (using a false-feedback paradigm) that their spontaneous thoughts about a specific form of physical activity were quite positive reported that they planned to devote more time to that activity in the coming week than participants who received no feedback (Rice & Fredrickson, 2017a; Study 3). Given that positive spontaneous thoughts about an activity seem to function as incentive salience, they may be one

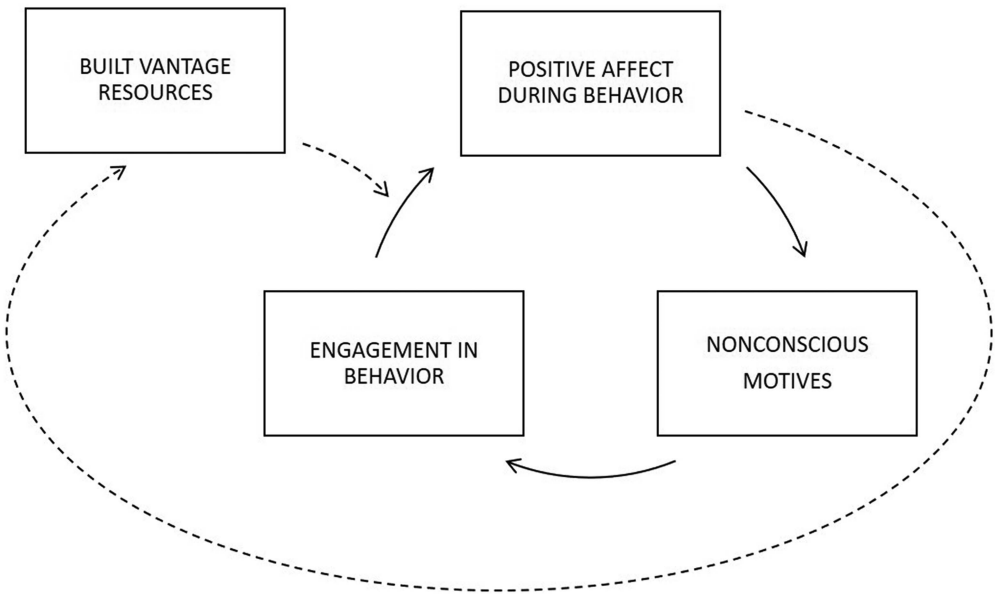

Figure 1. The upward spiral theory of lifestyle change. The inner loop is depicted in a solid line; the outer loop is depicted in a dashed line.

manifestation of the nonconscious motives that energize behavior in the inner loop.

Whereas the processes in the inner loop of the upward spiral theory are hypothesized to operate on the order of individual instances of behavior, the outer loop is thought to proceed over a longer time course. That arm of the model, which follows the broaden-and-build theory of positive emotions (Fredrickson, 1998, 2001, 2013), holds that when positive affect is reliably experienced during healthy behaviors, this recurrent affect builds an individual's biopsychosocial resources over time. A subset of these resources (e.g., cardiac vagal tone; Kok et al., 2013; prioritizing positivity; Van Cappellen, Catalino, & Fredrickson, 2018) may be considered vantage resources to the extent that they subsequently enable the individual to derive increasingly more positive affect from that positive health behavior. By amplifying the inner loop of the model (see Figure 1), increases in vantage resources correspond to increases over time in nonconscious motivation for the target behavior.

To illustrate how these processes may play out in daily life, consider the example of joining a new cycling group. Other members of the group may provide companionship and encouragement during rides or suggest their favorite routes, which may increase the pleasantness of cycling. The positive affect generated while riding together heightens incentive salience for cycling and associated cues (e.g., bike, helmet, water bottle, and other members of the cycling group), making them more likely to stand out when subsequently encountered in the environment or to spontaneously come to mind at any time. These perceptual and cognitive nudges may increase the likelihood that the individual will repeat the behavior (e.g., cycle with the group again). All the while, over time, the positive emotions experienced while cycling contribute collectively to the development of vantage resources, such as perceived social integration (the sense that one is embedded within a meaningful social network), which may further enrich future excursions with the group and augment the incentive salience of cycling.

The Present Research

The present research tested a hypothesized mechanism by which perceived social integration may relate to repeated physical activity behavior. Two waves of analyses drew data from a sample of midlife adults enrolled in an 18-month longitudinal study that tested separate hypotheses about positive emotions, meditation, and other wellness behaviors (Fredrickson et al., 2017). Given that perceived social integration could facilitate enjoyable social experiences during physical activity or enhance positive affect more broadly in daily life, the first set of analyses evaluated perceived social integration as a vantage resource with the capacity to amplify positive emotions experienced during physical activity over time. During the 11 weeks of daily reporting, participants attended weekly training sessions for one of two types of meditation (mindfulness [MM] or loving-kindness [LKM]) and were encouraged to practice at home; the trainings involved no instructions to change or increase physical activity. In addition to the potential for either meditation practice to increase perceived social integration as shown in other studies (cf., Adair, Fredrickson, Castro-Schilo, Kim, & Sidberry, 2018; Fredrickson, Cohn, Coffey, Pek, & Finkel, 2008), prior research has demonstrated the capacity for minimal daily reflection on social interactions to increase participants' sense of social connection (Kok & Fredrickson, 2010), so even the daily measures of social integration could plausibly boost participants' perceptions of social integration over time. Given these potential influences on perceived social integration, we tested whether increases in perceived social integration over time corresponded to increases in positive affect experienced during physical activity, consistent with the notion that perceived social integration functions as a vantage resource (Hypothesis 1).

Guided by the upward spiral theory, a second set of analyses evaluated a specific pathway by which perceived social integration may facilitate repeated physical activity using data collected across a 5-day span. We hypothesized that individuals who felt more socially integrated during a 24-hr period would be more likely to indicate that a bout of physical activity the following day felt more social (Hypothesis 2), and that instances of physical activity that were more social would be experienced as more enjoyable (Hypothesis 3). We predicted that, in turn, the positive affect experienced during an activity would be associated with the relative positivity of subsequent spontaneous thoughts about the activity (Hypothesis 4). Finally, we predicted that these spontaneous thoughts would forecast physical activity over the following 48 hr (Hypothesis 5). We used structural equation modeling to test this hypothesized path model.

The study was approved by the University of North Carolina, Chapel Hill Institutional Review Board and was planned according to applicable guidelines for the responsible and transparent conduct of research (Simmons, Nelson, & Simonsohn, 2011). The present research involved a secondary analysis of all viable data from the study; analyses were conducted and reported herein according to the same guidelines.

Method

Participants

The full study sample included 226 adults from the Chapel Hill community enrolled in a longitudinal study on wellness behaviors.[1] Given that the present research involved secondary analysis of previously collected data, a priori analyses to determine an optimal sample size were not possible (though such analyses were conducted in anticipation of primary analyses unrelated to the present research). Most participants identified as female (60%) and White or Caucasian (77%), although other ethnicities were represented (i.e., 1% American Indian or Native Alaskan, 5% Asian, 17% Black or African American, 4% Hispanic or Latino/Latina). Ages ranged from 34 to 65 ($M = 48.51$, $SD = 8.89$). Inspection of physical activity during the first week of daily reporting revealed that the study sample was relatively active upon enrollment. During that first week, participants indicated that they engaged in moderate or vigorous physical activity, on average, between 4 and 5 days per week ($M = 4.29$, $SD = 2.27$). The median value of time spent in moderate or vigorous physical activity during this period

[1] Data from this larger, National Institutes of Health-supported study (Grant R01CA170128) have been reported on elsewhere (Fredrickson et al., 2017, Study 2; Rice & Fredrickson, 2017b, Study 2) and will continue to support other and related investigations.

just exceeded half an hour each day (*Mdn* = 34.26 min/day). Participants received monetary compensation for completing the study as reported elsewhere (Fredrickson et al., 2017).

Procedures

In the first week of the study, participants completed a baseline lab visit, which involved providing biological samples and completing a variety of measures unrelated to the main themes of the present research. During the next 11 weeks, participants completed daily and biweekly questionnaires. Daily questionnaires included 24-hr measures of perceived social integration and physical activity, described in detail below, as well as other health-related behaviors: meditation, eating fruits and vegetables, smoking, and drinking alcohol. We chose to focus on physical activity, given that it is a health-promoting behavior (unlike smoking or drinking alcohol) that allows for social interaction (unlike meditation). We explored the hypothesized processes in the context of eating fruits and vegetables as well and discuss those findings in the online supplemental materials.

The questionnaires administered every other week included an event-reconstruction task (Grube, Schroer, Hentzschel, & Hertel, 2008) that guided participants through recalling the last time they were physically active. Participants were prompted to "think of the last time you engaged in walking or a moderate or vigorous physical activity for at least 10 minutes or more (e.g., walking, bicycling, digging, jogging)" and were advised not to consider sexual activity in this task. In addition to other items not included in the present analyses, participants were asked to indicate how long ago the focal event occurred. Only events that occurred within the preceding 24 hr were included in the present analyses to preserve the sequence of measures; other categorical response options for the timing question included a wider frame (i.e., 2–3 days ago, etc.) and thus could not reliably pinpoint the timing of the focal event relative to the daily reports.

During 6 weeks of the reporting period, participants attended a weekly meditation class (LKM or MM, depending on the condition to which they were randomly assigned at the beginning of the experiment; n_{LKM} = 116, n_{MM} = 110). These two meditation practices did not differentially alter daily positive emotions (Fredrickson et al., 2017), nor did they alter positive emotions experienced during physical activity. Although these forms of meditation (at least outside of the classes) may have been practiced in solitude, the focus of LKM, in particular, was social and thus could have altered participants' perceptions of social integration. It remained conceivable, then, that this randomized training may have influenced key variables in the present analyses (i.e., perceived social integration or sociality of physical activity), so we included condition as a covariate when appropriate.

Measures

Perceived social integration. A single item included in the daily questionnaires assessed perceptions of social integration during the previous day, "In the past 24 hours, how much did you feel socially integrated or 'on the same page' with others?" using a response scale that ranged from 1 (*not at all*) to 7 (*completely*).

Sociality during physical activity. Sociality during physical activity was assessed by a single item included in the biweekly questionnaires. In the context of the event-reconstruction task, participants reported on the sociality of the focal instance of physical activity that occurred within the past 24 hr, "To what extent would you consider this event social?" using a 5-point scale ranging from 0 (*not at all*) to 4 (*extremely*).

Positive affect during physical activity. The event-reconstruction task in the biweekly questionnaires also included a one-item measure of positive affect during the focal instance of physical activity. While reflecting on a specific bout of physical activity that occurred within the past 24 hr, participants were asked to indicate, "What is the most positive you felt?" using a response scale from 0 (*not at all*) to 4 (*extremely*).

Positivity of spontaneous thoughts. A single item included in the biweekly questionnaires prompted participants to estimate the general positivity of their spontaneous thoughts about physical activity as in previous research (Rice & Fredrickson, 2017a, 2017b): "What percentage of [the thoughts about physical activity] that pop into your head seem to be positive?"

Daily physical activity. Two dichotomous items included in the daily questionnaires asked whether participants had engaged in vigorous [moderate] physical activity (respectively) in the past 24 hr. If participants indicated having engaged in either type of activity, follow-up items prompted them to report on how long they were active (in minutes), and how positive they felt while they were active on a scale ranging from 0 (*not at all*) to 4 (*very*).

Analytic Strategy

Data reduction and multilevel modeling were completed using SAS 9.3, and structural equation models were estimated using Mplus 7.4 (Muthén & Muthén, 1998–2012). To evaluate change in perceived social integration and positive emotions during physical activity, we submitted all available data from the 11 weeks of daily reporting to separate univariate growth models (PROC MIXED) with daily observations nested within participants. After determining whether the type of meditation practice influenced the trajectory of change in either variable, perceived social integration and positive affect during physical activity were submitted to a multivariate growth model to assess whether change in one corresponded to change in the other (H_1).

To evaluate the hypothesized pathway from perceived social integration to repeated physical activity (H_2–H_5), data from the event-reconstruction reports about a specific instance of physical activity were merged with the data from the daily questionnaires. Figure 2 displays the measurement timeline. The combined measures of vigorous and moderate physical activity (in minutes) from the two daily reports following the event-reconstruction report were averaged to produce a measure of vigorous and moderate activity per day during the 48 hr following the measure of positive spontaneous thoughts. This time period was chosen as a reasonable interval to capture meaningful patterns of behavior based on the frequency with which participants engaged in physical activity at baseline. In rare instances where a single participant provided multiple qualifying cases over the 11-week reporting period, only the first complete case was used, resulting in a final sample of 143 complete cases, which is a sufficient sample size for testing a model including six variables (and 10 paths among them), according to several conventions for determining minimum acceptable sample sizes as a function of model complexity (e.g.,

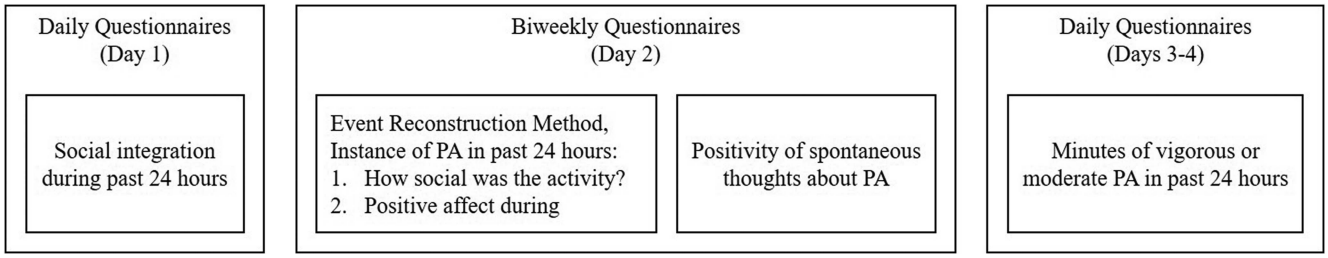

Figure 2. Measurement timeline for path analysis.

Bollen, 1989). See Figure 3 displays a diagram of the data-reduction process. See the online supplemental materials for more information, including analytic assumptions and diagnostics. Datasets used in the present analyses and a codebook are available online (https://osf.io/6gmjd/).

Results

Descriptive Statistics

Table 1 provides descriptive statistics pertaining to daily data submitted to the growth models, and Table 2 provides descriptive statistics pertaining to variables submitted to the path analysis.

Change in Perceived Social Integration, Positive Affect During Physical Activity, and Physical Activity

To determine whether participants' daily reports of perceived social integration, positive affect during physical activity, and minutes of physical activity changed over the 11 weeks, we estimated separate linear growth curve models with time (scaled in weeks) as a Level 1 predictor of daily reports. Preliminary analyses described in the online supplemental materials suggested that a linear model fit the perceived social integration data and positive affect data well and that the residual variances were heteroscedastic over time. In both cases, the effect of time was significantly different from zero, suggesting that on average, participants' daily experiences of perceived social integration increased linearly over the 11 weeks ($b = 0.036$, $SE = 0.007$, $p < .001$, 95% CI [0.023, 0.049]), as did daily experiences of positive affect during physical activity ($b = 0.010$, $SE = 0.005$, $p = .036$, 95% CI [0.001, 0.019]). Neither effect was moderated by condition.

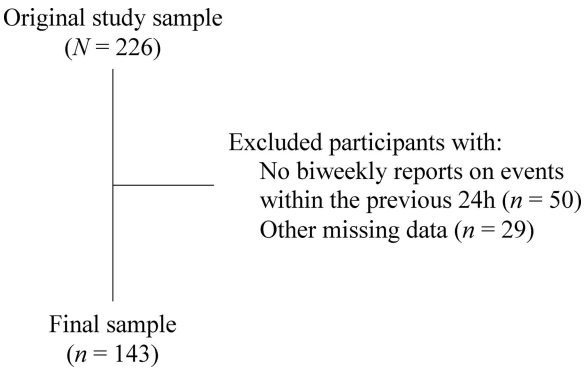

Figure 3. Data reduction process for path analysis.

Although the larger study was not designed or advertised as a physical activity intervention, participants' first several weeks of physical activity reports exhibited an initial spike followed by a lull and gradual rebound that is not uncommon in physical activity studies. Preliminary analyses ultimately suggested that the data were not well characterized by a quadratic effect (described in more detail in the online supplemental materials). However, physical activity data from Weeks 3–11 followed an approximately linear trend and thus were submitted to a linear model with heteroscedastic residual variance. The effect of time was not significantly different from zero, suggesting that, on average, there was no linear change in participants' daily physical activity after the second week of the study ($b = 0.17$, $SE = 0.22$, $p = .44$, 95% CI [−0.26, 0.59]). The effect was not moderated by condition.

Next, to test the hypothesis that changes in perceived social integration over time corresponded to changes in positive affect during physical activity, we estimated a multivariate linear growth model with uncorrelated residuals within time. We also estimated an analogous model with correlated within-time residuals, and a likelihood ratio test revealed that this alternative error structure significantly improved model fit ($\chi^2 = 440.8$, $df = 76$, $p < .001$). This analysis revealed significant covariance between the slope for perceived social integration and the slope for positive affect during physical activity (cov = 0.002, $SE = 0.0005$, $p < .001$), corresponding to a correlation of $r = .258$. This finding suggests that as hypothesized (H_1), increases in perceived social integration tended to co-occur with increases in positive affect during physical activity over the 11 weeks, a pattern consistent with the notion that perceived social integration may function as a vantage resource for physical activity maintenance.

Pathway From Perceived Social Integration to Subsequent Physical Activity

To test the hypothesized pathway from perceived social integration to subsequent physical activity (H_2–H_5) and expand upon the observed association between change in perceived social integration and change in positive affect during physical activity (H_1), we estimated a progressive series of structural equation models. In the first step, we constructed a simple path model in which prior perceived social integration predicted sociality during physical activity, sociality predicted positive affect during physical activity, positive affect predicted positivity of spontaneous thoughts about physical activity, and positivity of spontaneous thoughts predicted

Table 1
Descriptive Statistics and Correlations Among Daily Data Submitted to Growth Models

Variable	*n*	Min	Max	Mean	*SD*	1	2
1. Perceived social integration in the past 24 hr	13,018	1	7	4.53	1.46		
2. Positive affect during physical activity in the past 24 hr	7,541	0	4	2.59	1.05	.44**	
3. Minutes of physical activity in the past 24 hr	13,029	0	720	34.46	49.96	.13**	.21**

Note. $N = 226$. Participants were only prompted to report on positive emotions during physical activity during daily reports when they indicated having engaged in moderate or vigorous physical activity in the past 24 hr, hence the smaller number of observations.
* $p < .05$. ** $p < .01$.

subsequent physical activity behavior. Although we had no hypotheses related to randomized condition (LKM vs. MM), we nevertheless added it to the model and allowed it to predict all other variables. This model did not fit the data well ($\chi^2 = 11.60$, $df = 6$, $p = .07$, root-mean-square error of approximation [RMSEA] = 0.081, comparative fit index [CFI] = 0.86, standardized root-mean-square residual [SRMR] = 0.068) relative to commonly accepted standards (Hu & Bentler, 1999). However, modification indices suggested adding a direct path from perceived social integration to positive affect during physical activity. Though we expected the association between perceived social integration and positive affect during physical activity to be fully mediated by sociality during physical activity, this direct effect is consistent with the support observed for H_1 above: that perceived social integration goes hand in hand with positive affect during physical activity. It also connects to broader findings regarding sociality and positive emotions (i.e., that those who feel more socially integrated experience more positive emotions in daily life, which might be incidentally captured by the measure of positive affect during physical activity; Diener & Seligman, 2002). For these statistical and theoretical reasons, we included the direct path from perceived social integration to positive affect during physical activity in a subsequent model.

The revised model demonstrated satisfactory fit ($\chi^2 = 4.61$, $df = 5$, $p = .47$, RMSEA = 0.000, CFI = 1.000, SRMR = 0.041), and a likelihood ratio test confirmed that the improvement in model fit was statistically significant ($\chi^2 = 6.99$, $df = 1$, $p < .01$). Inspection of the individual paths revealed that all predicted effects (H_2–H_5) were statistically significant and, as expected, experimental condition was not significantly associated with any variables of interest;[2] Figure 4 displays parameter estimates. Further, bootstrapping analysis with 1,000 samples revealed that the total indirect effect (IE) of prior perceived social integration on subsequent physical activity through sociality, positive emotions, and positivity of spontaneous thoughts was significant (IE = 0.48, $SE = 0.28$, 95% CI [0.11, 1.26]).

Alternative Models

Although the revised model demonstrated impressive fit to the data, other plausible alternatives remain. A series of additional models were estimated to rule out several such possibilities. The first aimed to test whether perceived social integration on the day of a specific instance of physical activity directly predicted positive affect during that activity. Perceived social integration and sociality during physical activity were reconfigured in the model, such that they were drawn from measures on the same day (i.e., the day of the instance of physical activity in question) and jointly predicted positive affect during physical activity (thus removing the indirect path from perceived social integration to sociality to positive affect during physical activity). This model demonstrated poor fit to the data ($\chi^2 = 15.14$, $df = 6$, $p = .02$, RMSEA = 0.103, CFI = 0.76, SRMR = 0.075), and subsequent models retained the measure of perceived social integration from the day prior to the focal instance of physical activity. Table 3 displays a comparison of fit statistics corresponding to each of the models tested.

The second alternative model accounted for the possibility that positive affect during physical activity could precede sociality during physical activity—whether incidentally, if one is exercising at a lower intensity (demonstrated elsewhere to be more enjoyable; Ekkekakis et al., 2011) thus allowing greater respiratory capacity for conversation, or more directly, perhaps by exhibiting affiliative cues such as smiling. Because both measures were drawn from the event reconstruction method with reference to a bout of physical activity that occurred on the previous day, it is not possible to infer order from the measurement timeline. The rest of the model matched the structure and content of the revised model. However, this second alternative model also demonstrated poor fit to the data ($\chi^2 = 16.87$, $df = 5$, $p = .01$, RMSEA = 0.129, CFI = 0.69, SRMR = 0.083).

The third alternative model accounted for the possibility that positive spontaneous thoughts may precede positive affect during physical activity. The structure and content of this model exactly matched the revised model, except that the order of the variables representing positive affect during physical activity and positivity of spontaneous thoughts about physical activity was reversed. Again, this model demonstrated poor fit to the data ($\chi^2 = 19.50$, $df = 5$, $p = .002$, RMSEA = 0.142, CFI = 0.63, SRMR = 0.085). Given the unimpressive fit of each of these alternatives models, the revised model described above was retained.

Discussion

The present research explored the dynamics of perceived social integration and positive affect during physical activity and evaluated one theoretically derived pathway by which perceived social integration, a purported vantage resource, and sociality during specific instances of physical activity together forecast later engagement in physical activity. Linear growth curve modeling revealed that as perceptions of social integration increased during the

[2] Omitting condition as a covariate does not change the pattern of results.

Table 2
Descriptive Statistics and Correlations Among Study Variables for Path Analysis

Variable	Min	Max	Mean	*SD*	1	2	3	4
1. Perceived social integration	1	7	4.58	1.41				
2. Sociality of physical activity	0	4	1.26	1.23	.27**			
3. Positive affect during physical activity	0	4	2.47	.96	.28**	.27**		
4. Positivity of spontaneous thoughts about physical activity	0	10	7.55	2.32	.20**	.08	.30**	
5. Average physical activity (in minutes, over 2 days)	0	195	36.26	39.98	.10	.11	.13	.21*

Note. $n = 143$.
* $p < .05$. ** $p < .01$.

targeted 11 weeks, so did positive affect experienced during physical activity (H_1). Subsequent analyses expanded on that association using structural equation modeling, which revealed that prior perceived social integration predicted sociality during physical activity (H_2), and through sociality, positive affect experienced during physical activity (H_3). In turn, positive affect experienced during physical activity predicted the positivity of spontaneous thoughts about physical activity in general (H_4), which then predicted the duration of physical activity enacted over the following 48 hr (H_5).

As hypothesized, the findings provide evidence in support of the upward spiral theory of lifestyle change (Fredrickson, 2013; Van Cappellen, Catalino, et al., 2018). Specifically, the growth models reveal how within-person changes in perceived social integration (conceptualized as a vantage resource) correspond to changes in positive affect during physical activity, which the inner loop of the framework specifies should reinforce sustainable patterns of behavior. Although the upward spiral theory holds that vantage resources are one cause of increasing positive affect during positive health behaviors, the analysis reported here does not support causal claims. It remains plausible, for instance, that increasing positive affect while physically active leads to increasing perceptions of social integration. Also possible is that changes in other health-related variables, such as lower inflammation or improved mental health, produce gains both in perceived social integration as well as in positive affect during physical activity. Nevertheless, the pattern of results is also consistent with our theory-based prediction that perceived social integration functions as a vantage resource. Because participants' levels of physical activity did not increase over the 9 weeks of daily reporting analyzed, the present data did not allow a test of whether the observed increases in perceived social integration and positive affect during physical activity aligned with increases in physical activity duration over a period of several months. However, extant research has documented this association (Rhodes & Kates, 2015; Williams et al., 2008, 2012; Woolley & Fishbach, 2016), and the densely repeated measures in the present study enabled a test of the fundamental processes described in the upward spiral model that may unfold from day to day.

Indeed, path analysis informed by the inner loop suggests that a psychological resource (perceived social integration) enacted in an instance of a wellness behavior (sociality during activity) is associated with greater positive affect experienced during that behavior, and positive affect is associated with nonconscious incentive salience (indexed as positive spontaneous thoughts), which predicts subsequent behavioral engagement. By incorporating per-

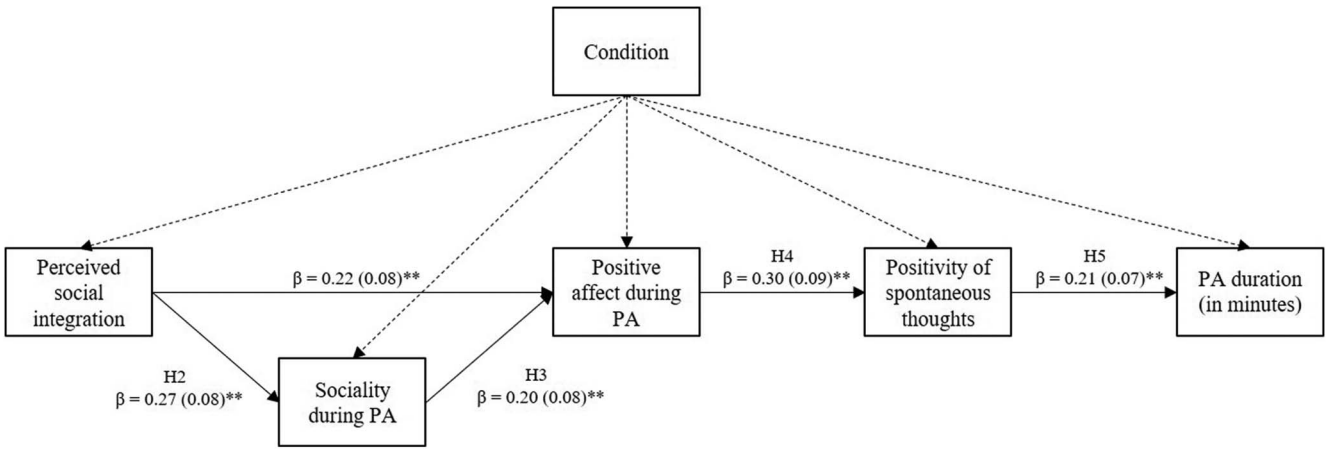

Figure 4. Perceived social integration predicts physical activity through social behavior, positive emotions during behavior, and positive spontaneous thoughts about the behavior ($n = 143$). Standard errors are given in parentheses. The total indirect effect (IE) of perceived social integration on subsequent duration of physical activity (vigorous or moderate) is statistically significant (IE = 0.54, $SE = 0.29$, 95% CI [0.14, 1.44]). Condition was included as a covariate, though it was not expected to have a significant effect on the model. PA = physical activity. * $p < .05$. ** $p < .01$. *** $p < .001$.

Table 3
Fit Indices for Each of the Structural Equation Models

Model	χ^2	*df*	*p*	RMSEA	CFI	SRMR
Original	11.60	6	.07	.081	.86	.068
Revised (Final)	4.61	5	.47	.000	1.0	.041
Alternative 1	15.14	6	.02	.103	.76	.075
Alternative 2	16.87	5	.01	.129	.69	.083
Alternative 3	19.50	5	<.01	.142	.63	.085

Note. *df* = degrees of freedom; RMSEA = root-mean-square error of approximation; CFI = comparative fit index; SRMR = standardized root-mean-square residual.

ceived social integration as a vantage resource, the present research extends prior work that had focused more exclusively on the inner loop of the upward spiral model (Rice & Fredrickson, 2017a; Van Cappellen, Catalino, et al., 2018). Further, by carefully staggering a sequence of daily diary reports over time, the ecological validity of the present work complements more tightly controlled laboratory studies to test the hypothesis that positive spontaneous thoughts (as incentive salience) predict subsequent behavior (cf., Rice & Fredrickson, 2017a, 2017b).

Many of the measures included in the present research are subject to limitations that commonly apply to data collection involving intensive questionnaires. To minimize participant burden, many constructs of interest were distilled to single items, but were aggregated over days (as opposed to over items) when justified. Likewise, all data analyzed in the present research were self-reported, and many variables involved recall of affective states or cognitions within the past 24 hr, and so are susceptible to recall biases as well as other cognitive biases commonly associated with self-reported data.

Although most of the variables in the final model were assessed with regard to a specific timeframe (e.g., a specific instance of physical activity in the past 24 hr), one limitation of the present study is that the measure of positive spontaneous thoughts available did not specify a reporting period. This brief item was chosen to minimize participant burden before subsequent work found that measures of spontaneous thoughts with more temporal precision could be implemented successfully (e.g., positivity of spontaneous thoughts about a specific activity in the past 24 hr; Rice & Fredrickson, 2017a, Study 1). Future studies that can reasonably accommodate more rigorous measures of spontaneous thoughts might instead opt for a thought-listing task (Rice & Fredrickson, 2017a, Study 2) or ecological momentary assessment to improve confidence in reliability. Future work may also model frequency of spontaneous thoughts, which may be orthogonal to thought valence. Although positivity of spontaneous thoughts was selected as our present variable of interest in accordance with the upward spiral theory and prior research (Rice & Fredrickson, 2017a, 2017b), it is plausible that thought frequency moderates the association between thought valence and subsequent behavior, potentially amplifying the motivational nudging of positive spontaneous thoughts as they become more frequent.

More theoretically, the temporal precision of the model may be muddied somewhat by the assumption that sociality precedes positive affect during the particular instance of physical activity probed during the event-reconstruction method. While this is certainly a reasonable order to assume, it is not the only reasonable effect that may occur; it is plausible that people who feel more pleasant while engaged in solo activity look more approachable (e.g., by expressing positive affect) or are more likely to initiate social interactions with others (Waugh & Fredrickson, 2006). Alternatively, the two constructs may be connected by a third variable not explored in the present study, for example, that people who are exercising below ventilatory threshold may enjoy the activity more (Ekkekakis et al., 2011) and incidentally also have greater capacity to talk and engage with others around them. Even though an alternative model with positive affect preceding sociality did not demonstrate compelling model fit (see Table 3, Alternative Model 2), the order of those two constructs in the measured data cannot be determined.

Despite these limitations, the present study provides a valuable opportunity to evaluate a novel theory within affective science and may inform subsequent research aimed at developing evidence-based behavior change interventions. For example, interventions may target experiences during physical activity by encouraging social exercise or other strategies for increasing positive affect during physical activity (e.g., listening to music or opting for enjoyable activities such as sports, games, dance, or outdoor activities, etc.), or may consider other strategies for capitalizing on positive emotions that arise during physical activity (e.g., journaling enjoyable aspects of the behavior in addition to tracking more conventional features of the activity, such as intensity and duration).

One review of prior studies that tested affect during exercise as a predictor of subsequent behavior found that the four high-quality studies that met inclusion criteria all demonstrated statistically significant positive correlations, yet reported highly variable effect sizes ranging from $r = .18$ to $r = .51$ (Rhodes & Kates, 2015). Although further research is needed to understand the factors that govern when and for whom positive affect during physical activity most robustly predicts subsequent behavior, the present research helps to clarify one pathway by which positive affect may be generated and thus reinforce physical activity behavior. In the present research, 20% of the (statistical) effect of perceived social integration on positive affect during physical activity was accounted for by sociality during physical activity, suggesting that other factors may account for substantial variance in that relationship alone. Taking into account the various other factors that may separately predict positive affect during physical activity, much work remains to be done to understand how to optimally enhance enjoyment during physical activity. With respect to the process by which positive affect forecasts subsequent behavior, post hoc analyses of the (statistical) effect of positive affect on physical activity revealed that 41% of the total effect was accounted for by positivity of spontaneous thoughts. This contributes to cross-sectional evidence that positive spontaneous thoughts mediate the association between liking and wanting, and experimental evidence that positive affect during an activity generates subsequent positive spontaneous thoughts (Rice & Fredrickson, 2017a).

We do not, however, advise researchers building on this work to prompt participants to generate positive thoughts about physical activity; since these thoughts would not be spontaneous, they could inadvertently give the impression that one doesn't feel that physical activity is very pleasant if such thoughts are difficult to recall (Schwarz et al., 1991). Future research may instead evaluate strat-

egies that could ultimately enable capitalizing on positive spontaneous thoughts in interventions, perhaps by training participants to notice and savor such cognitions when they arise organically, following prior evidence that perceptions of positive spontaneous thoughts about a particular physical activity may shape intentions to engage in that activity (Rice & Fredrickson, 2017a, Study 3). Ultimately, additional research is needed to expand the evidence base on how positive spontaneous thoughts may be related to subsequent behavior.

Other research may further clarify the nuances of the social processes implicated in the present findings. For instance, prior research demonstrated that participants estimated the slope of a hill to be less steep when standing at the bottom with a friend than when alone (Schnall, Harber, Stefanucci, & Proffitt, 2008). Does the presence of a companion similarly lower perceived barriers to physical activity by making it seem less intimidating or aversive? Or do companions have the effect of compelling individuals into physical activity despite barriers, only to find that the activity is not as unpleasant as they may have anticipated, or that social interaction provides a pleasant distraction from any physical discomfort? Future research may likewise explore alternative mediators of the observed association between perceived social integration and positive emotions during physical activity.

Although the primary aim of the present research was to characterize one path by which social connection may facilitate healthy behaviors such as physical activity, it will also be valuable to better understand nonsocial sources of positive affect during physical activity, as well as moderators of these effects. The upward spiral theory of lifestyle change is not restricted to social processes, but rather specifies fundamental cognitive and motivational consequences of positive affect. As such, many of the same downstream effects may follow from positive affect, even in the absence of direct social connection. For example, people who feel more socially integrated may incidentally experience positive affect more frequently throughout their daily lives, increasing the likelihood that they happen to feel pleasant while exercising (this may be one interpretation of the observed direct path from perceived social integration to positive affect during physical activity). Other research suggests that harmonious passion (i.e., passion for a favorite activity that is pursued autonomously; Vallerand et al., 2003) is associated with positive affect during physical activity as well as positive spontaneous thoughts (Rice & Fredrickson, 2017b). Identifying various sources of positive affect during physical activity and understanding for whom those sources are most dependable may ultimately create a more diverse (and potentially useful) catalog of possible intervention targets.

A strong evidence base documents the importance of social connection to physical health and longevity (e.g., Holt-Lunstad et al., 2010; Seeman, 1996). The present results contribute to this literature by illuminating one pathway along which feelings of social integration may facilitate sustainable patterns of physical activity. The findings described herein suggest that social connection has the potential to alter affective experiences during physical activity as well as spontaneous thoughts about physical activity in ways that may increasingly draw people toward a pattern of repeated behavioral engagement that supports health and longevity.

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