Same-day, cross-day, and upward spiral relations between positive affect and positive health behaviours

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Running Head: POSITIVE AFFECT AND HEALTH BEHAVIOURS

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Objective: This project investigated same-day and lagged (i.e., from one day to the next) associations between daily positive affect and three distinct positive health behaviours: physical activity, fruit and vegetable intake, and meditation. Cross-day analyses also examined the role of positive affect felt during the targeted health behaviours.

Design: Secondary data analyses used a 9-week daily diary study in which midlife adults (N = 217) were randomized to learn one of two contemplative practices (i.e., mindfulness meditation or loving-kindness meditation) while reporting nightly on their emotions and health behaviours.

Results: Results of same-day analyses revealed positive associations, both between-person and within-person, for the three positive health behaviours with daily positive affect. Results of lagged analyses revealed that positive affect experienced during fruit and vegetable intake on a given day predicted next-day fruit and vegetable intake, and that fruit and vegetable intake on a given day predicted next-day positive affect.

Conclusion: The observed same-day relations between daily positive affect and engagement in positive health behaviours illuminate one path through which positive affect may contribute to health. The observed cross-day relations reveal a need for interdisciplinary research on mechanisms through which fruit and vegetable intake may shape next-day positive affect.

Keywords: positive psychology; nutrition; physical fitness; contemplative science; upward spiral theory of lifestyle change

Habitual experiences of positive affect, meta-analyses show, are consistently linked to longevity (Chida & Steptoe, 2008; Zhang & Han, 2016). Multiple mechanisms, likely operating in conjunction, have been identified to account for this link. These include (a) salutogenic biological profiles (Kok et al., 2013); Ong, Benson, Zautra, & Ram, 2018); Wilson et al., 2017); (b) stress-buffering (Blevins, Sagui, & Bennett, 2017); Okely, Weiss, & Gale, 2017); Robles, Brooks, & Pressman, 2009); (c) resource-building (Cohn, Fredrickson, Brown, Mikels, & Conway, 2009); Fredrickson, Cohn, Coffey, Pek, & Finkel, 2008); Ouweneel, Blanc, & Schaufeli, 2012); and (d) health behaviours (Ironson, Banerjee, Fitch, & Krause, 2018); Kubzansky & Thurston, 2007), each known to be associated with positive affect. The current investigation targets this last proposed mechanism, health behaviours, and specifically examines the links between positive affect and the subset of health behaviours that, when enacted, enhance physical health, collectively known as "positive health behaviours." The behaviours we examine include physical activity, fruit and vegetable intake, and meditation. Although each promotes wellness differently, fits into people's lives differently, requires different skills, and may contribute differently to people's sense of meaning and identity, we target this set because health-promoting behaviours tend to cluster (Lippke, Nigg, & Maddock, 2012).

Two forms of positive affect are likely to be related to positive health behaviours: enjoyment of the day and enjoyment of the specific health-related activity. We assessed the first form, enjoyment of the day (a.k.a., "daily positive affect"), as an aggregate of ten different positive emotions endorsed in end-of-day reports (e.g., peak experiences of joy, interest, gratitude, or love on that day). Because positive affective valence has been demonstrated to increase agency (Chang, Algoe, & Chen, 2017), ambient positive affect may implicitly energize activity engagement (e.g., Cameron, Bertenshaw, & Sheeran, 2018). An alternative direction of causality may run from positive health behaviours to the enjoyment of life: Those who possess personal resources such as physical health and resilience should be better equipped to manage ups and downs in daily living, which can make days more enjoyable (Cohn et al., 2009). Either direction of causality predicts same-day associations between daily positive affect and positive health behaviours. Examining cross-day associations offers one possibility to disentangle the two causal directions.

The second form of positive affect we investigated is enjoyment of the activity, assessed as positive feelings during specific bouts of a positive health behaviour (e.g., “How positive did you feel, on average, while you were physically active [today]?” reported retrospectively at end-of-day). The affective rewards of positive health behaviours have been found to predict long-term behavioural maintenance (Cohn & Fredrickson, 2010)) Williams, Dunsiger, Jennings, & Marcus, 2012). Experimental studies show that positive affect felt during a given activity creates implicit motives for that activity that augment subsequent behavioural effort (Aarts, Custers, & Marien, 2008; Custers & Aarts, 2005;) Rice & Fredrickson, 2017). Repeated enjoyment of an activity can also build personal resources, such as physical fitness or social integration, which may subsequently amplify later enjoyment of the activity (Rice, Adair, Tepper, & Fredrickson, 2019). These two pathways linking enjoyment of the activity to sustained engagement are central to the Upward Spiral Theory of Lifestyle Change (Fredrickson, 2013); Van Cappellen et al., 2018). Although tests of these mechanisms are beyond the scope of the current paper, this theorizing drew us to examine enjoyment of specific positive health behaviours alongside enjoyment of the day.

Among the positive health behaviours examined here, physical activity has been studied most, with within-day links to positive affect well-established (Reed & Ones, 2006). Physical activity produces transient boosts in positive affect both during physical activity (if below the ventilatory or lactate threshold; Ekkekakis, Parfitt, & Petruzzello, 2011), Emerson & Williams, 2015) as well as over the ensuing 4-5 hours (Ekkekakis et al., 2011;) Wichers et al., 2012;) for a meta-analysis, see Reed & Ones, 2006). Recent evidence also suggests within-day reciprocal associations: In a study using ecological momentary assessment with low-active, overweight adults (*N* = 59), beyond reporting more positive affect on days on which they exercised, participants were also more likely to exercise on days when they experienced more positive affect earlier in the day (Emerson, Dunsiger, & Williams, 2018). Additionally, a review of 24 studies concluded that positive affect experienced *during* physical activity forecasts people's physical activity in the weeks and months ahead, whereas positive affect experienced *after* physical activity does not (Rhodes & Kates, 2015). It remains unknown, however, whether this conclusion also applies to shorter timespans, such as from one day to the next.

Although links between positive affect and fruit and vegetable intake have been less studied, a recent cross-sectional study of college students (*N* = 1270) found positive affect to increase linearly as a function of fruit and vegetable intake (Warner, Frye, Morrell, & Carey, 2017) see also Brookie, Best, & Conner, 2018). A 3-week daily diary study of young adults (*N* = 281) also found same-day associations between positive affect and fruit and vegetable intake, plus cross-day associations, with yesterday's fruit and vegetable intake predicting today's positive affect, and *not* vice versa (White, Horwath, & Conner, 2013, but see Conner, Brookie, Richardson, & Polak, 2015). A subsequent randomized controlled trial with young adults (*N* = 171) found that increasing fruit and vegetable intake raised participants' reports of vitality and flourishing, but not positive mood (Conner, Brookie, Carr, Mainvil, & Vissers, 2017). No studies have yet examined whether positive affect felt *during* fruit and vegetable consumption (vs. that felt any time during the targeted day) also plays a role.

The third positive health behaviour we target is meditation because one of the most common reasons that people report for practicing meditation is to maintain their general health and well-being (Burke, Lam, Stussman, & Yang, 2017). Our team conducted two 9-week daily diary studies of midlife adults (total $N = 339$) who initiated a regular practice of either mindfulness meditation or loving-kindness meditation (Fredrickson et al., 2017; Study 2 of which reports on the same sample as used here). Both practices produced week-by-week gains in enjoyment of the day, indexed as the aforementioned aggregate of ten positive emotions. Multilevel models also revealed same-day associations with positive affect, both between-persons and within-persons, with the latter being stronger for loving-kindness meditation (Fredrickson et al., 2017). Cross-day effects and links with positive affect felt *during* meditation (vs. that felt any time during the targeted day) remain unknown.

Here, we conducted secondary data analyses of a 9-week daily diary study in which midlife adults ($N = 217$) were randomized to learn one of two contemplative practices (i.e., mindfulness meditation or loving-kindness meditation) while reporting nightly on their emotions and health behaviours (Fredrickson et al., 2017, Study 2). If a given health behaviour was reported, participants also reported how much, plus the affect they experienced during the behaviour. We examined within-day and lagged (i.e., over one day) associations between two forms of positive affect (i.e., across the day and during health behaviours) and the three positive health behaviours identified above. For comparison purposes, we also examined negative affect and one negative health behaviour, namely, alcohol consumption, which has also been linked to same-day positive affect and therefore is important to distinguish from behaviours that promote health (Bold et al., 2016).

Based on the research literature reviewed above, we hypothesized that same-day positive associations would exist between the three targeted positive health behaviours (i.e., physical activity, fruit and vegetable intake, and meditation) and enjoyment of the day. Moreover, we hypothesized that these predicted positive associations would emerge both between persons and within persons. To address unanswered research questions about cross-day associations between positive health behaviours and positive affect, we also conducted within-person lagged analyses using these same variables. These allowed us to investigate whether yesterday's positive health behaviours predict today's positive affect and vice versa. Lagged analyses also examined the role of enjoyment during the targeted health-related activity. Specifically, we examined the within-person, lagged, cross-day associations between the positive affect people retrospectively reported experiencing during the three positive health behaviours and their next-day engagement in those behaviours. Finally, for comparison purposes, we conducted similar same-day and cross-day analyses with daily negative affect, and also with the negative health behaviour of alcohol use.

Method

Participants

Participants were midlife adults aged 35 to 64 (Inclusion criteria: interest in lifestyle change and meditation; daily internet access; fluent in English. Exclusion criterion: established meditation practice.) Procedures for recruitment and screening have been described elsewhere (Fredrickson et al., 2017; Online Supplementary Material [OSM] lists prior publications from this NIH-supported study [R01CA170128]). Following informed consent, participants (N = 231) were randomized to one of two meditation workshops: mindfulness meditation (MM; n = 113) or loving-kindness meditation (LKM; *n* = 118). Ultimately, 14 participants were excluded, resulting in a final sample of *N* = 217 (for MM, *n* = 106; for LKM, *n* = 111; for details, see CONSORT diagram in OSM). In the analysis sample, mean age was 48.6 years (*SD* = 9.0). The majority of participants were female (59.9%) and Caucasian (76.5%), and 18.0% were Black. (For more demographic details, see Table 1 [Study 2] in Fredrickson et al., 2017).

Given that the present research involved secondary analyses, a priori power analyses to determine optimal sample size were not possible (they were, however, conducted for the unrelated primary analyses). Post-hoc power analyses were conducted using the "sjstats" package in R 3.3.1 for small, medium, and large effect sizes. A very small effect size of 0.1 (Cohen's *D*) with 217 subjects requires 50 observations per person to achieve power of 0.8. A medium effect size of 0.5 requires 50 individuals with three observations, and a large effect size of 0.8 requires 30 individuals with two observations each. We conclude that this investigation (with 63 assessment days, and a 79% mean response rate) is adequately powered to detect even very small effect sizes.

Procedure

All procedures were approved by the Institution Review Board of the University of North Carolina at Chapel Hill. Data were collected over five waves (from May 2013 to May 2015), in which participants completed 11 weeks of daily diary reporting. This study includes data from the last nine weeks of data collection, as the initial two weeks were used to get participants accustomed to completing the reports. Of the focal nine weeks, the first six weeks included the weekly meditation workshops, held in small groups with parallel formats for MM or LKM. For MM, practitioners were guided to direct their attention to the contents of consciousness in the present moment, with targets of consciousness progressively expanded over the six weeks, from breathing and hearing (Week 1), the body (Week 2), emotions (Week 3), thoughts (Week 4), and choiceless awareness (Week 5), with Week 6 being review and integration. For LKM, practitioners were guided to self-cultivate warm and friendly feelings, with social targets progressively expanded over the six weeks, from a loved one (Week 1), oneself (Week 2), an acquaintance (Week 3), a difficult person (Week 4), and all beings (Week 5), with Week 6 being review and integration (For more details, see Fredrickson et al., 2017). Participants' data were aligned at the date of the first workshop session they attended.

Measures

Affect

Daily affect was assessed each evening using the modified Differential Emotions Scale (mDES). The mDES includes 20 items to assess the degrees to which respondents experience different emotions, both positive and negative, within a given time frame (Fredrickson, 2013). Ten positive emotions (i.e., amusement, awe, gratitude, hope, inspiration, interest, joy, love, pride, and serenity) and ten negative emotions (i.e., anger, contempt, disgust, embarrassment, fear, guilt, hate, sadness, shame, and stress) are assessed, each with a trio of adjectives (e.g., "awe, wonder, amazement" and "contemptuous, scornful, disdainful"). For each item, participants are asked to indicate the greatest degree to which they experienced the given feelings over the past 24 hours using a 5-point scale in which 0 = *Not at all*; 1 = *A little bit*; 2 = *Moderately*; 3 = *Quite a bit*; and 4 = *Extremely*. Composite scores for daily positive affect (PA-day) and daily negative affect (NA-day) were obtained by calculating the mean of the relevant ten items within each day. Respective reliabilities (omega coefficients) for between-person differences and within-person changes were 0.87 and 0.96 for positive affect and 0.79 and 0.96 for negative affect. (Details on reliability calculations are in Fredrickson et al., 2017).

Health behaviours and affect during health behaviours

Participants reported daily, retrospectively at end-of-day, on physical activity, fruit and vegetable intake, meditation practice, alcohol consumption, and tobacco use during the study. These assessments use the event reconstruction method, a survey approach validated to be comparable to ecological momentary assessment in minimizing retrospection bias (Grube, Schroer, Hentzschel & Hertel, 2008). Questions regarding health behaviours asked whether the participant engaged in the behaviour that day, and if so, how much they engaged in the given behaviour, and how positive and (separately) how negative they felt during the behaviour. For this study, we excluded tobacco use because few participants reported it. We use the terms "PA-behaviour" and "NA-behaviour" to distinguish these from the above-mentioned "PA-day" and "NA-day."

For physical activity, participants were first asked, "In the last 24 hours, have you engaged in any [vigorous/moderate] physical activity?" Examples of vigorous activity included running, swimming, aerobics, sports, and heavy yard work. Examples of moderate activity included brisk walking, bicycling, vacuuming, and gardening. If participants responded, "yes" to vigorous or moderate physical activity, they were next asked to report how long they were active (in minutes). Next, using a 0-4 scale (devised for this study) and separately for vigorous and moderate physical activity, participants indicated how [positive/negative] they felt, on average, while they were physically active. For analyses, we summed responses across vigorous and moderate physical activity to create a composite variable of total minutes spent engaged in physical activity. Similarly, we computed means across vigorous and moderate physical activity regarding positive and negative affect (separately) felt during activity engagement.

Regarding diet, participants were asked, “Approximately how many cups of FRUIT did you eat in the last 24 hours?” This question was repeated for vegetables. Response options ranged from 0 to 6+ in one-cup intervals. Examples of serving volumes were provided (e.g., 4 large strawberries = ½ cup; 1 large ear of corn = 1 cup). Again using our 0-4 scale, participants then indicated how [positive/negative] they felt, on average, while “consuming the fruits and/or vegetables.” For analyses, we summed the separate fruit and vegetable volume responses to form one variable that assessed the combined cups of fruits and vegetables consumed.

For meditation, participants indicated whether they engaged in the behaviour. If “yes,” they were asked, “How much time (in minutes) did you spend on meditation in the last 24 hours? If there were multiple sessions, make sure to add them all together.” Again using our 0-4 scale, participants then indicated how [positive/negative] they felt, on average, while meditating.

For alcohol use, participants were again asked to endorse whether they engaged in the behaviour. If they responded “yes,” they were then asked, “Approximately how many alcoholic drinks did you consume in the last 24 hours?” Again using our 0-4 scale, participants then indicated how [positive/negative] they felt, on average, while drinking alcohol.

Additional measures, used as covariates in sensitivity analyses, are described in OSM.

Analytic Methods

We conducted analyses using R 3.3.1 and the “lme4” package. We first examined same-day relations between each of the four health behaviours (i.e., the three positive health behaviours plus alcohol consumption) and daily positive affect (i.e., PA-day). Given that Study 2 in Fredrickson et al. (2017) used the same sample as used here, we flag the small subset of results regarding meditation that were reported previously. Next, to explore possible causal order, we then examined lagged relations (e.g., physical activity yesterday predicting positive affect today). To test same-day relations, we fit four separate models, nesting daily reports (Level 1) within persons (Level 2). We asked: Is there a same-day association between PA-day and each of the four health behaviours? To test cross-day relations, we fit twelve separate, two-level models, nesting daily reports (Level 1) within persons (Level 2). We first asked: Does higher engagement in a health behaviour predict next-day PA-day? Then we asked: Does higher endorsement of PA-day predict next-day behaviours? Dependent variables across models were PA-day, and each of the four health behaviours. The behaviours of physical activity and time spent meditating were rescaled to allow for easier computation. Minutes spent engaged in physical activity were divided by 100 and minutes spent engaged in meditation were divided by ten. Finally, we further tested cross-day relations in which positive affect felt during each health behaviour on one day (PA-behaviour) predicts engagement in the health behaviour the next day. For completeness, we tested parallel analyses with negative affect (NA-day and NA-behaviour) as well as sensitivity analyses of moderation by randomized condition (MM vs. LKM) or by a set of covariates selected a priori (i.e., biological sex, age, ethnicity, body mass index, systemic inflammation). For brevity, these analyses are only summarized (with detailed results in OSM). Details on our model building approach, including preliminary growth curve models, are available in OSM. Importantly, each predictor was included both as a person mean-centered variable (Level 1) and as an individual mean over time variable (Level 2), to test for within-person differences and between-person differences, respectively.

Results

Preliminary Analyses

Comparing MM and LKM conditions revealed no between-group differences in PA-day, physical activity engagement, cups of fruits and vegetables consumed, minutes spent meditating, or number of alcoholic drinks consumed. Intraclass correlations (ICCs) indicated that considerable variance in each was attributable to between-person effects (i.e., from 25% to 70%). Regarding PA-behaviour, participants in MM reported higher levels of positive affect during physical activity and fruit and vegetable intake. No between-group differences emerged in PA-behaviour for meditation or alcohol use. Means by condition (MM vs. LKM) and statistical details of these analyses are presented in OSM.

Planned preliminary growth curve models (reported in detail in OSM) revealed linear increases within individuals over the nine weeks for PA-day (reported previously in Fredrickson et al., 2017) and fruit and vegetable intake ($\beta = 0.08$, $p = .01$). A linear decrease in time spent meditating also emerged ($\beta = -0.10$, $p = .0001$), which was not altogether unexpected, given that the meditation workshops ended three weeks before the end of daily reporting. No within-person change over time was evident for physical activity or alcohol use. No differences between MM and LKM groups emerged in any growth curve models. Post-hoc analyses revealed same-day associations—both between-persons ($\beta = .28$, $p = .03$) and within-persons ($\beta = .10$, $p < .0001$)—between time spent meditating and cups of fruits and vegetables consumed (see OSM for details).

Same-day Associations

Fixed effects models that tested same-day relations between PA-day and health behaviours are presented in Table 1. For each behaviour examined, a positive, significant within-person association was evident between the behaviour and PA-day. These within-person results indicate that participants who engaged in the behaviour more frequently than their own daily average reported higher positive affect for that day. Excepting for alcohol use, a positive, significant between-person association was also evident between all health behaviours and PA-day. These between-person results indicate that, on average, those participants who engaged in the given behaviour more frequently than others reported higher intensity daily positive affect.

Cross-day Associations

Tests of cross-day associations can shed light on possible within-person causal directions between positive affect and health behaviours. (We note here that *between-person* cross-day associations with PA-day, reported in OSM Tables, are virtually identical to between-person same-day associations.) Models in which PA-day predicted the behaviours of meditation and alcohol use did not converge, nor did the model in which PA-behaviour for meditation predicted next-day meditation practice. Thus, of the 12 models we fit, results are available for nine.

Yesterday's health behaviours predicting today's daily positive affect

Results for the lagged associations between health behaviours on one day and PA-day on the next are summarized here, with statistical details in Table S1 in OSM. In all models, PA-day demonstrated significant autoregressive effects ($\beta = .09$, $p < .01$). The pattern of these autoregressive effects revealed that participants who experienced higher than their own average intensity of PA-day on one day experienced higher intensity PA-day the next day. Significant, within-person lagged relationships were found for the behaviours of fruit and vegetable intake and alcohol consumption: On average, participants who reported eating higher than their own average amount of fruits and vegetables on one day experienced higher intensity PA-day the next day ($\beta = .01$, $p < .05$); participants who reported drinking a greater number of alcoholic drinks than their own average experienced lower intensity PA-day the next day ($\beta = -.01$, $p < .01$).

Yesterday's daily positive affect predicting today's health behaviours

Results for the lagged associations between PA-day on one day and health behaviours on the next are summarized here, with statistical details in Table S2 in OSM. Both physical activity and fruit and vegetable intake demonstrated significant, positive autoregressive effects (Phy: β = .04, $p < .001$; FVI: (β = .25, $p < .001$), indicating that participants who were physically active for more time than their own average, or who consumed a greater amount of fruits and vegetables than their own average were likely to be active for longer and eat greater amounts of fruits and vegetables the next day. However, no significant within-person associations emerged for yesterday's PA-day predicting next-day health behaviours.

Yesterday's positive affect during health behaviours predicting today's health behaviours

Results for the lagged associations between positive affect experienced during a given health behaviour (PA-behaviour) on one day and the degree of engagement in that same health behaviour the next day are summarized here, with statistical details in Table S3 in OSM. (The growth curve for fruit and vegetable intake could not be included in the model in order to reach convergence.) Positive, between-person relationships emerged for the behaviours of physical activity (p = .01; β unavailable due to convergence issues) and fruit and vegetable intake (β = .60, $p < .001$), in which participants who, on average, reported higher levels of PA-behaviour for each of these behaviours reported higher levels of those behaviours, on average, the next day. Additionally, a positive, within-person effect for fruit and vegetable intake emerged (β = .06, p = .002), in which participants who on a given day reported higher PA-behaviour for fruit and vegetable intake (relative to their own average) were likely to consume greater amounts of fruits and vegetables the next day. No other significant effects emerged.

Parallel analyses for negative affect

We repeated each analysis reported above replacing PA-day and PA-behaviour with NA-day and NA-behaviour, respectively, and report the results in the OSM (see Section 5 and Tables S4-S7). The overall pattern of mostly null results suggests that the associations reported herein are specific to positive affect. The only significant same-day association was a negative within-person link suggesting that devoting more time to physical activity on a given day was linked to experiencing less intense negative affect that day (β = -.02, $p < .001$). The cross-day associations also revealed a between-person effect such that those who reported higher intensity negative affect during alcohol consumption on one day reported more alcohol consumption the next day (β = .32, $p < .001$), plus a within-person effect such that more alcohol consumption on one day predicting higher intensity negative affect the next day (β = .01, $p = .01$).

Sensitivity analyses

We also explored whether the results reported here were moderated by randomized condition (MM vs. LKM) or by demographic (i.e., biological sex, age, ethnicity) or health-related variables (i.e., body mass index, systemic inflammation). Table 2 provides a summary of the primary findings of the current investigation. The note that accompanies Table 2 identifies the few cases in which primary findings are qualified by the results of sensitivity analyses (reported in OSM, Section 6). The overall pattern suggests that, among positive health behaviours, the primary findings for physical activity and fruit and vegetable intake were robust to sensitivity analyses and need no qualifications, whereas those regarding meditation need to be qualified. Specifically, the between-person effect for meditation was not sufficiently robust to survive sensitivity analyses and the within-person effect for meditation was stronger for those randomized to LKM versus MM (β = .02, $p = .02$; reported in Fredrickson et al., 2017). One intriguing result for the negative health behaviour of alcohol consumption was that participants randomized to learn LKM (versus MM) showed a weaker, within-person link between alcohol use and daily positive affect (β = -.02, $p = .046$).

Discussion

Positive affect, when frequently experienced, has been established by meta-analyses to predict longevity (Chida & Steptoe, 2008; Zhang & Han, 2016). One of several mechanisms that may account for this long-term benefit of frequent positive affect hinges on the positive health behaviours that positive affect may motivate (Van Cappellen et al., 2017). Alternatively, to the extent that positive health behaviours produce positive affect, the link between positive affect and longevity might be explained by the specific health-related behaviours that give rise to enjoyment. The current investigation was undertaken to illuminate these various behavioural accounts by assessing the links between two forms of positive affect—enjoyment of the day and enjoyment of specific health-related behaviours—and three types of positive health behaviours—physical activity, fruit and vegetable intake, and meditation. Specifically, we examined their same-day, cross-day, and day-to-day upward spiral relations. As points of contrast, we also conducted analyses with parallel measures of negative affect and with the negative health behaviour of alcohol consumption.

The overall findings are summarized in Table 2. First, we hypothesized that our data would replicate past findings of same-day relations between daily positive affect and each of the three positive health behaviours (e.g., Reed & Ones, 2006; White et al., 2013; Fredrickson et al., 2017). As shown in Table 2, for each distinct behaviour, significant same-day associations were evident, as indicated by both between-person effects and within-person effects. The significant between-person effects indicate that individuals in midlife who (a) are more physically active, (b) eat more fruits and vegetables, and (c) meditate more (relative to other midlife individuals), also report experiencing a range of daily positive emotions to higher degrees. Evidence for these three individual differences is complemented by evidence for day-to-day processes that fluctuate within individuals. That is, the significant within-person effects indicate that on days in which midlife adults (a) are more physically active, (b) eat more fruits and vegetables, and (c) meditate more (relative to other days), they report experiencing positive emotions to higher degrees. (See Table 2 for qualifications to the effects for meditation.) Because within-person effects better match theoretical questions about change over time (Curran & Bauer, 2011), these day-by-day variations underscore the need for cross-day analyses, which can begin to unpack whether positive health behaviours increase enjoyment of the day, whether enjoyment of the day increases positive health behaviours, or whether both directions of causality are viable. Regardless, the observed associations appear to be specific to positive affect: Same-day links between the three positive health behaviours and daily negative affect did not emerge, with the sole exception of evidence that days with more physical activity are marked by lower intensities of negative affect.

In contrast to the hypothesized same-day associations, which all received empirical support, results for our research questions regarding cross-day effects were mixed. We note that two of the three lagged models for meditation did not converge, and in the one that did converge, no significant within-person effect emerged. Likewise, although all three lagged models for physical activity converged, no significant within-person effects emerged for that activity either. By contrast, for the positive health behaviour of eating fruits and vegetables, two of the three lagged within-person effects emerged as significant. First, when individuals ate more fruits and vegetables on one day, they enjoyed their next day more, as indicated by their self-reports of experiencing a range of daily positive emotions to higher degrees. Importantly, the reciprocal lagged effect was not significant, that running from daily positive affect on one day to fruit and vegetable intake on the next. The finding of cross-day affective benefits for fruit and vegetable intake in our midlife adult sample joins prior similar evidence from young adult samples (Conner et al, 2017; White et al., 2013), each of which showed comparable (small) effect sizes. In both age groups, this effect was not mirrored by reciprocal evidence that yesterday's totality of positive affect predicted today's fruits and vegetables intake.

To our knowledge, the present investigation is the first to test the association between the positive affect people experienced specifically during fruit and vegetable intake on one day and the amount of fruit and vegetable intake on the next. This is the second of the two lagged associations that received empirical support. Taken together, the two significant cross-day findings regarding fruit and vegetable consumption suggest a day-to-day upward spiral dynamic in which the enjoyment people felt while eating their fruits and vegetables yesterday predicts eating more fruits and vegetables today, which in turn forecasts having a more enjoyable day tomorrow. Again, these associations appear to be specific to positive affect: Cross-day links between the three positive health behaviours and daily negative affect did not emerge, with the sole exception of evidence that people who experienced more negative affect during meditation on one day, meditated less the next day.

Whereas negative affect provides one point of contrast in this investigation, the negative health behaviour of alcohol consumption provides another. Although tests of same-day associations suggest that days on which our midlife participants consumed more alcohol were days with higher positive affect, tests of lagged associations suggest that these days were followed by days with both reduced positive affect and increased negative affect. Further underscoring that excessive alcohol consumption is a negative health behaviour, the more negative affect that participants felt while drinking on one day predicted more alcohol consumption the next day, a finding that may reflect the long-terms risks of drinking to self-medicate negative feelings (Crum et al., 2013). Our findings suggest that although alcohol consumption on a given day is linked with higher positive affect that same day, which may reflect a short-term gain, it also appears to bring long-term pain, in terms of worsened affect the next day, which may prompt greater consumption the next. Intriguingly, sensitivity analyses suggest that the observed short-term gain of alcohol consumption is lessened among participants randomized to learn loving-kindness meditation, a finding that aligns with the idea that natural rewards, like interpersonal warmth, may help people to curb unhealthy pleasures (c.f., Garland, Atchley, Hanley, Zubieta & Froeliger, 2019)

The results of this investigation provide robust evidence for same-day links between daily positive affect and two of the most commonly studied positive health behaviours, namely, physical activity and fruit and vegetable intake. More limited evidence emerged for similar affective links for meditation. When we examined lagged associations from one day to the next, a pictured emerged to suggest that greater fruit and vegetable intake may somehow support enjoyment of the next day as well. We hasten to add that causality cannot be inferred from the results reported here. Randomized controlled trials are called for, such as the one that found well-being-enhancing results when young adults consumed more fresh fruits and vegetables (Conner et al., 2017).

We also underscore that the present investigation only examined lagged associations on the scale of one day to the next. Longer lag times between positive affect and positive health behaviours, such as from one month, season, or year to the next, or shorter lag times, such as within a day may also be present and should be targets of future study. Indeed, past evidence suggests that beyond the affective boosts in the hours that follow physical activity, significant lagged effects from positive affect to greater activity engagement have emerged that are both longer (over months; Williams et al., 2012) and shorter (over hours; Emerson et al., 2018) than the cross-day effects examined here. The observed cross-day effects for fruit and vegetable intake may also reflect that eating, for most people, is a daily imperative, whereas physical activity, meditation, and alcohol consumption are optional activities.

Although not the target of study here, consistent with the observation that health-promoting behaviours tend to cluster (Lippke et al., 2012), our initial descriptive evidence suggests that, in the process of learning to meditate, participants' daily positive affect increased over time. Additionally, a side benefit appears to have emerged in terms of an increase in participants' fruit and vegetable consumption. Moreover, post-hoc analyses of same-day associations between meditation and fruit and vegetable intake revealed both between-person and within-person effects that are consistent with the benefits of mindful eating (e.g., Jordan, Wang, Donatoni, & Meier, 2014). This latter pattern of results indicates both that people who meditate more (relative to other people) eat more fruits and vegetables and also that days that include more minutes of meditation (relative to other days) include more servings of fruits and vegetables. Further research on same-day and cross-day associations among distinct positive health behaviours is warranted.

The research design used here has both strengths and weaknesses. Strengths include the sample size and the densely repeated assessments of affect and behaviour over 9 weeks. Weaknesses include that it relies entirely on participants' retrospective self-reports of affect and behaviour and therefore carries the limitations of retrospective self-reports. To a degree, those limitations are lessened because participants only reported on one day at a time or one event at a time (e.g., a bout of physical activity on that day), rather than on their affect and health behaviours in general. Nevertheless, future work would benefit from implicit or ecological momentary assessments of affect and objective assessments of behaviour. Another weakness is that the study relied on secondary data analyses that were not pre-registered. Additionally, generalization to other age groups and to other ethnicities and cultures may not be warranted.

Also unanswerable from this research is why eating more fruits and vegetables yesterday might lead to more positive affect today. From a psychological perspective, perhaps when people are able to acquire, prepare, and consume more fruits and vegetables they feel more virtuous or efficacious that day and the next. The finding that positive affect felt during fruit and vegetable consumption predicts increased next-day consumption aligns with a recent randomized study that found that when exciting language is used to describe vegetables (e.g., “twisted carrots” and “dynamite beets”) consumption at a large university cafeteria increased (Turnwald, Boles, & Crum, 2017). From a nutrition perspective, perhaps the micro-nutrients, fiber, or water content of fruits and vegetables, or their effects on anti-inflammatory, antioxidant, or microbiome processes support the experience of same-day and next-day positive affect. Other explanations for this link do not assume a causal effect, but instead reflect “third variable” effects. As one example, to the extent that people cycle through healthy and unhealthy eating patterns, they may feel that if they ate healthy yesterday, they deserve to indulge themselves (on sweets or comfort foods) today, and that those unhealthy foods created today’s positive affect. Undermining this alternative explanation, however, is the significant, positive autoregressive effect for fruit and vegetable intake, which revealed that study participants’ intake levels did not cycle between high and low consumption. Rigorous tests of plausible mechanisms that may account for the observed lagged link between eating more fruits and vegetables on one day and greater enjoyment of the next day will require interdisciplinary collaborations between nutrition and affective scientists. We encourage such pursuits and look forward to the fruits of them.

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Author Contributions

BLF designed the study, secured funding, and wrote the paper. CA analyzed the data and wrote sections of the paper. PVC collaborated with the study design and edited the final manuscript.

Table 1. Same-day associations between daily positive affect and health behaviours.

	Fixed Effects			
	b	*β*	*95% CI*	*p*
Intercept	1.52**	1.82	[1.38,1.67]	<.001
Phy_C	.16**	.07	[.13,.20]	<.001
Phy_Avg	.65**	.17	[.31,.99]	<.001
Time	.02**	.05	[.01,.03]	<.001
-2LL	13500.88			
	b	*β*	*95% CI*	
Intercept	1.23**	1.82	[1.03,1.44]	<.001
FVI_C	.03**	.04	[0.02,0.04]	<.001
FVI_Avg	.13**	.25	[0.08,0.17]	<.001
Time	.02**	.04	[0.01,0.02]	<.001
-2LL	13816.73			
	b	*β*	*95% CI*	
Intercept	1.52**	1.82	[1.32,1.73]	<.001
Med_C	.02**	.02	[.00,.03]	.01
Med_Avg	.15*	.11	[.02,.28]	.02
Time	.02**	.05	[.01,.03]	<.001
-2LL	13771.95			
	b	*β*	*95% CI*	
Intercept	1.76**	1.82	[1.64,1.88]	<.001
Alc_C	.08**	.07	[.06,.10]	<.001
Alc_Avg	-.02	-.02	[-.12,.08]	.75
Time	.02**	.04	[.01,.03]	<.001
-2LL	13970.17			

Note. Phy = physical activity; FVI = fruit and vegetable intake; Med = meditation; Alc = alcohol consumption. *_C indicates person mean-centered variable, or within-person effects. *_Avg indicates individual means of variable, or between-person effects.

Table 2. Summary of Results for Hypotheses and Research Questions on Same-day and Lagged Associations Between Positive Affect and Positive Health Behaviours.

Hypothesis Supported: Significant Same-Day Between-Person Effects for:
Physical Activity ←→ Daily Positive Affect
Fruit and Vegetable Intake ←→ Daily Positive Affect
Meditation ←→ Daily Positive Affect [a, b]
Hypothesis Supported: Significant Same-day Within-Person Effects for:
Physical Activity ←→ Daily Positive Affect
Fruit and Vegetable Intake ←→ Daily Positive Affect
Meditation ←→ Daily Positive Affect[a]
Research Questions Addressed: Significant Lagged Within-Person Effects for:
One Day's Positive Affect During Fruit and Vegetable Intake (FVI) → Next Day's FVI
One Day's FVI → Next Day's Daily Positive Affect

Note: [a] Sensitivity analyses revealed that this effect was no longer significant when condition interaction effects were added to the model and that results indicated a stronger within-person effect for loving-kindness meditation than for mindfulness meditation.
[b] Sensitivity analyses revealed that this effect was no longer significant when covariates were added to the model.

Online Supplementary Material (OSM) for Fredrickson, Arizmendi & Van Cappellen's

Same-day, Cross-day and Upward Spiral Relations Between

Positive Affect and Positive Health Behaviours

Section 1: Prior publications and CONSORT diagram

Data from this larger, NIH-supported study (R01CA170128) have been reported on elsewhere (Fredrickson et al., 2017; Fredrickson et al., 2019; Major, Le Nguyen, Lundberg, & Fredrickson, 2018, Study 1); Rice & Fredrickson, 2017b, Study 2), Rice et al., 2019) and will continue to support other and related investigations. Although associations between affect and individual health behaviours in this sample have been reported in a subset of these prior publications (physical activity: (Rice et al., 2019; Rice & Fredrickson, 2017b); meditation: (Fredrickson et al., 2017, Study 2), Fredrickson et al., 2019) the present manuscript examines novel hypotheses and research questions, reports on a broader range of health behaviours, and includes both same-day and cross-day analyses.

Additional References (cited only in this OSM section and not the main manuscript)

Fredrickson, B. L., Arizmendi, C., Van Cappellen, P., Firestine, A. M., Brantley, M. M., Kim, S. L., … Salzberg, S. (2019). Do Contemplative Moments Matter? Effects of Informal Meditation on Emotions and Perceived Social Integration. *Mindfulness*, *10*(9), 1915–1925. https://doi.org/10.1007/s12671-019-01154-2

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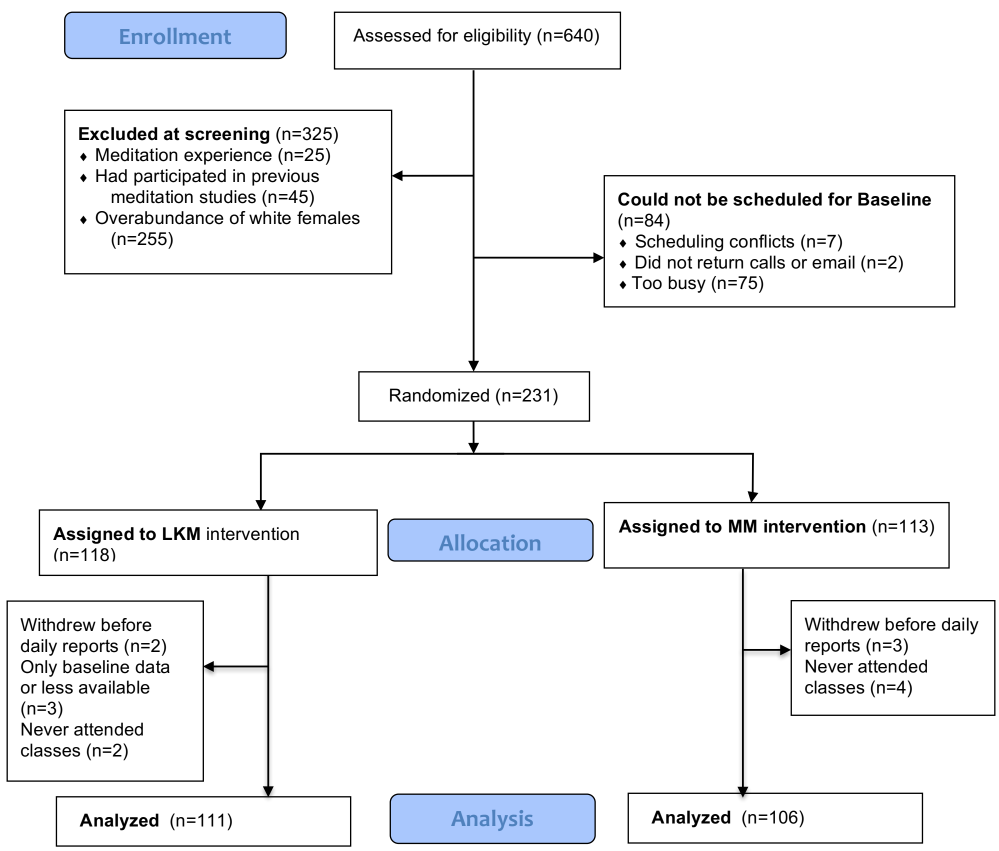
Rice, E. L., & Fredrickson, B. L. (2017b). Of Passions and Positive Spontaneous Thoughts. *Cognitive Therapy and Research*, *41*(3), 350–361. https://doi.org/10.1007/s10608-016-9755-3

CONSORT Diagram of flow of participants through recruitment and randomization



Section 2: Additional Measures

Participants were also assessed for body composition (Body Mass Index, BMI) and systemic inflammation (C-reactive protein, CRP) at study intake. We include these as covariates in sensitivity analyses (together with demographic characteristics) to assess whether initial markers of physical health influenced the associations between predictor and outcome variables. For BMI, weight was assessed using an electronic scale. Participants were asked to remove their shoes and stand still on the middle of the scale. Next, participants were asked to remove any hats or hair ornaments, stand with feet flat and heels together, and look straight ahead to assess height. BMI was then calculated from the weight and height (kg/m^2). For CRP, fasting morning blood draws (between 7 and 10 a.m.) were centrifuged on site and resulting plasma samples were delivered to LabCorp (www.labcorp.com) for latex immunoturbidimetry assay.

Section 3: Analytic Model Building Details

Model building occurred in two stages. In Stage 1, linear growth curve models were fit to assess whether there was an overall increase or decrease in the dependent variables over the course of the study. Randomized condition (MM or LKM) was included as a Level-2 covariate to test whether any linear trends differed by condition. This linear trend was included at all stages of the model to detrend the data (Curran & Bauer, 2011;) Wang & Maxwell, 2015) an approach that removes the potential confound of growth or decline over time from the estimates of within-person relations. (Results from Stage 1 for PA-day and NA-day were also reported in Fredrickson et al., 2017; those results are reported again for this work as important precursors to Stage 2 analyses.) In Stage 2, PA-day, or the health behaviour were added as a predictor to each model to determine whether there were same-day and/or lagged (from one day to the next) associations between the variables. Each predictor was included both as a person mean-centered variable (Level 1) and as an individual mean over time variable (Level 2), to test for within-person differences and between-person differences, respectively. All models were estimated using restricted maximum likelihood (REML) estimation. We report sensitivity analyses in Sections 7 and 8 of this OSM. In these, we again checked for main effects of randomized condition as well as interaction effects, crossing both person mean-centered and mean levels of the given predictor with condition (MM vs. LKM) to test whether within-person effects, between-person effects, or both differed by condition. Additional sensitivity analyses assessed whether any observed effects remained after including the covariates of age, sex, ethnicity, BMI, and CRP levels.

Additional Reference (cited only in this OSM section and not the main manuscript)

Wang, L. (Peggy), & Maxwell, S. E. (2015). On disaggregating between-person and within-person effects with longitudinal data using multilevel models. *Psychological Methods*, *20*(1), 63–83. https://doi.org/10.1037/met0000030

Section 4: Details of Preliminary Analyses

Averaging daily reports across the nine week period, PA-day did not differ significantly between those in the MM condition (*M* = 1.89, *SD* = .73) and those in the LKM condition (*M* = 1.74, *SD* = .68; *t*[212] = 1.62, 95%CI [-.03, .34], *d* = .22, *p* = .11). The intraclass correlation (ICC) was 0.68, indicating that about two-thirds of the variance in PA-day was attributable to between-person differences. Additionally, there were no significant differences between MM and LKM groups on minutes spent engaged in physical activity (divided by 100: MM: *M* = .33, *SD* = .26; LKM: *M* = .34, *SD* = .27; *t*[215] = -.30, 95%CI [-.08,.06], *d* = .04, *p* = .76), cups of fruits and vegetables consumed (MM: *M* = 4.38, *SD* = 1.94; LKM: *M* = 3.93, *SD* = 2.06; *t*[215] = 1.66, 95%CI [-.08,.98], *d* = .22, *p* = .10), minutes spent meditating (divided by 10: MM: *M* = 1.39, *SD* = .67; LKM: *M* = 1.44, *SD* = .8; *t*[211] = -.47, 95%CI [-.24,.15], *d* = .06, *p* = .64), or number of alcoholic drinks consumed (MM: *M* = .54, *SD* = .93; LKM: *M* = .70, *SD* = .94; *t*[215] = -1.21, 95%CI [-.40,.10], *d* = .16, *p* = .23). The variances attributable to between-person differences were about 30% for physical activity (*ICC* = .28), about 70% for fruits and vegetables (*ICC*=.68), about 25% for time spent meditating (*ICC* = .26), and about 50% for alcohol use (*ICC*=.51).

When examining levels of reported PA-behaviour, significant differences did emerge between MM and LKM groups on PA-behaviour for physical activity (MM: *M* = 2.75, *SD* = .89; LKM: *M* = 2.43, *SD* = .87; *t*[150] = 2.20, 95%CI [.03,.60], *d* = .36, *p* = .03) and on PA-behaviour for fruit and vegetable intake (MM: $M = 2.67$, $SD = 1.06$; LKM: $M = 2.36$, $SD = .97$; $t[210] = 2.21$, 95%CI [.03,.58], $d = .30$, $p = .03$), with those in the MM group reporting higher levels of positive affect during both behaviours. No significant differences emerged between MM and LKM groups on PA-behaviour for meditation (MM: $M = 2.45$, $SD = .84$; LKM: $M = 2.38$, $SD = .75$; $t[209] = .90$, 95%CI [-.12,.31], $d = .12$, $p = .37$) or PA-behaviour for alcohol use MM: $M = 2.25$, $SD = 1.00$; LKM: $M = 2.02$, $SD = .91$; $t[172] = 1.60$, 95%CI [-.05,.51], $d = .24$, $p = .11$).

Next, as Stage 1 of our model building, we fit five separate linear growth curve models, with time included as a Level 1 predictor, and PA-day and each health behaviour as the outcomes, respectively. Results suggest that, on average, PA-day ($b = .017$, 95%CI [.01,.03], $SE = .004$, $\beta = .04$, $p < .0001$) (reported originally in Fredrickson et al., 2017) and fruit and vegetable intake ($b = 0.03$, 95%CI [.001,.06], $SE = 0.01$, $\beta = 0.08$, $p = .01$) increased within individuals. Time spent meditating also decreased within individuals ($b = -.04$, 95%CI [-.06,-.02], $SE = .01$, $\beta = -.10$, $p = .0001$), which is not altogether unexpected, given that the meditation workshops ended three weeks prior to the end of daily reporting. Results revealed no change in time spent physically active ($b = .00$, 95%CI [-.00,.01], $SE = .00$, $\beta = .01$, $p = 0.23$) or in the number of alcoholic drinks consumed ($b = .01$, 95%CI [-.01,.02], $SE = .01$, $\beta = .02$, $p = .28$).

As justification for including both between-person and within-person effects for the slope and intercept in each model, the AIC for the each of the models including time as a random effect was smallest (*AICs* = 8538.74 – 34846.78).

Next, we added randomized condition as both a main and interaction effect with time to the growth curve models. As in Fredrickson et al. (2017), no significant effects for condition emerged either in the initial levels of PA-day or in the rate of growth of PA-day, suggesting that participants in both MM and LKM workshops similarly experienced overall increases in daily positive affect over the course of the study. Similarly, no significant effect emerged for randomized condition on initial levels or growth rates of time spent physically active, fruit and vegetable intake, time spent meditating, or alcohol consumption.

Ultimately, we retained the growth curve in the models when PA-day, fruit and vegetable intake, and time spent meditating were the outcomes and, to avoid overfitting of the model, excluded the growth curve when time spent physically active, and alcohol consumption were the outcomes. Because we found no condition effects at this stage of the model, condition effects are only tested in sensitivity analyses.

Post-hoc analyses revealed positive same-day associations—both between-person (b = .40, 95%CI [.04,.76], SE = .18, β = .28, p = .03) and within-person (b = .08, 95%CI [.05,.11], SE = .02, β = .10, $p < .0001$)—between time spent meditating and the amount of fruit and vegetable intake. Cross-day effects could not be estimated, however, because the model would not converge.

Section 5: Parallel Analytic Models with Negative Affect

Preliminary analyses. Averaging daily reports across the nine week period, NA-day did not differ between those in the MM condition (M = .47, SD = .37) and those in the LKM condition (M = .48, SD = .35; t[214] = -.10, 95%CI [-.10, .09], d = .01, p = .92). The intraclass correlation (ICC) was 0.50, indicating that about half the variance in daily negative affect was attributable to between-person differences. When examining negative affect experienced during health behaviours, no significant differences emerged between MM and LKM groups on levels of NA-behaviour for physical activity (MM: M = .25, SD = .39; LKM: M = .35, SD = .56; t[132] = -1.31, 95%CI [-.26,.05], d = .21, p = .19), fruit and vegetable intake (MM: M = .14, SD = .29; LKM: M = .15, SD = .30; t[214] = -.25, 95%CI [-.09,.07], d = .03, p = .80), mediation (MM: M = .30, SD = .44; LKM: M = .31, SD = .39; t[210] = -.07, 95%CI [-.11,.11], d = .01, p = .95), or alcohol use (MM: $M = .29$, $SD = .53$; LKM: $M = .29$, $SD = .45$; $t[169] = -.02$, 95%CI [-.15,.14], $d = .004$, $p = .98$).

As reported previously (Fredrickson et al., 2017), results revealed no change in levels of NA-day over the 9-week reporting period ($b = .00$, 95%CI [-.00,.01], $SE = .00$, $\beta = .00$, $p = .86$). When we next added randomized condition as both a main and interaction effect with time to this growth curve model, no significant effects for condition emerged either in the initial levels of NA-day or in the rate of growth of NA-day. To avoid overfitting, we excluded the growth curve from subsequent models of NA-day.

Same-day associations. To examine relations between NA-day and health behaviours within the same day, we fit four separate models in which NA-day is the outcome and each health behaviour is the independent variable. Table S4 reports the results of these models. Only one significant effect emerged, specifically a negative, within-person association between time spent physically active and NA-day. This sole effect indicates that participants who engaged in physical activity for longer than their own daily average reported lower negative affect for that day.

Cross-day associations. We examined the lagged associations between NA-day and health behaviours, first predicting today's NA-day from health behaviours undertaken yesterday, then predicting health behaviours today by NA-day experienced yesterday. We finished by predicting health behaviours today by NA-behaviour yesterday. We fit twelve separate models: four in which NA-day is the outcome and each health behaviour is the predictor, four in which each of the four health behaviours is the outcome and NA-day is the predictor, and finally, four in which each of the four health behaviours is the outcome and NA-behaviour is the predictor. The models in which NA-day predicted the behaviours of meditation and alcohol use did not converge leaving a total of ten models.

Table S5 reports the results for the lagged associations between health behaviours on one day and NA-day on the next. In all models, NA-day demonstrated significant autoregressive effects. The pattern of these autoregressive effects revealed that participants who reported higher than their own average level of NA-day on one day experienced less intense NA-day the next day. Only one significant effect emerged, specifically a positive, within-person lagged association for the behaviour of alcohol consumption. Participants who reported drinking a greater number of alcoholic drinks than their own average experienced higher intensity NA-day the next day.

Table S6 presents the results for the lagged associations between NA-day on one day and health behaviours on the next (physical activity and fruit and vegetable intake only, due to convergence issues with the models for other behaviours). As for PA-day, no significant within-person associations emerged for yesterday's NA-day predicting next-day health behaviours.

Finally, Table S7 present the results for the lagged associations between NA-behaviour on one day and the degree of engagement in that health behaviour the next day. A negative, between-person relationship emerged between NA-behaviour for meditation and time spent meditating, in which participants who, on average, reported higher levels of NA-behaviour during meditation, reported less time spent meditating, on average, the next day. A positive, between-person relationship emerged between NA-behaviour for alcohol use and alcohol use, such that those who, on average, report higher levels of negative affect during alcohol use reported consuming greater amounts of alcohol, on average, the next day.

Section 6: Sensitivity Analyses for Same-day Associations:

Effects of randomized condition. We also tested the effects of randomized condition (i.e., MM vs. LKM) as (a) a main effect, (b) an interaction effect with the mean-centered predictor variable, and (c) an interaction effect with the average level of the predictor variable. In models with physical activity as the predictor and daily affect as the outcome, a significant between-person interaction effect between condition and physical activity emerged (*b* = -.42, 95%CI [-.78,-.06], *SE* = .18, β = -.11, *p* = 0.02), revealing an overall positive association between more time spent physically active and NA-day (*b* = .30, 95%CI [.03, .56], *SE* = .13, β = .08, *p* = 0.02); however, that positive relationship was slightly attenuated for participants in the LKM condition. Additionally, the within-person effect of physical activity on NA-day was no longer significant (*b* = -.02, 95%CI [-.05, .00], *SE* = .01, β = -.01, *p* = .08). No significant condition effects or changes in other predictors were observed with physical activity as the predictor and PA-day as the outcome. In models with fruit and vegetable intake as the predictor and daily affect as outcomes, the significance and sign of each independent variable did not change after adding condition effects to the model. Additionally, no condition effects or condition interaction effects were significant for any of the models with fruit and vegetable intake as the predictor. In models with time spent meditating as the predictor and daily affect as the outcomes, a significant, within-person condition interaction effect emerged, indicating that participants in the LKM condition demonstrated a stronger link between spending more time meditating than their personal average and PA-day (*b* = .02, 95%CI [.003, .05], *SE* = .01, β = .02, *p* = .02; an effect previously reported in Fredrickson et al., 2017). There were no longer significant main effects for within-person (*b* = .00, 95%CI [-.01, .02], *SE* = .01, β = .00, *p* = .67) or between-person (*b* = .08, 95%CI [-.13, .29], *SE* = .11, β = .06, *p* = .44) associations between time spent meditating and PA-day. With number of alcoholic drinks as the predictor and PA-day as the outcome, there was a significant, within-person condition interaction effect (*b* = -.04, 95%CI [-.08, -.001], *SE* = .02, β = -.02, *p* = .046), in which participants in the LKM condition demonstrated a weaker relationship between alcohol use and PA-day. No significant condition main or interaction effects or changes in the significance or sign of the other predictors were evident when alcohol was the predictor and NA-day was the outcome.

Inclusion of covariates. The sign and significance of effects for each health behaviour (when it was a predictor of either PA-day or NA-day) did not change with addition of the covariates of sex, age, ethnicity, BMI, or CRP, except in the case where time spent meditating was the predictor. In that case, the between-person association between time spent meditating and PA-day was no longer significant (*b* = .10, 95%CI [-.04, .22], *SE* = .06, *p* = 0.16). In all models with PA-day as the outcome, only ethnicity demonstrated a significant effect (*b* = -.42 - -.37, *SE* = .11 - .12, β = -.26 -.15, *p* = .001 - .01), with White participants reporting PA-day than non-White participants when controlling for all other variables in the model. With NA-day as the outcome, only age demonstrated a significant effect (all *bs* = -.01, *SE* = .00 - .03, all βs = -.07, *p* = .004- .01), with older participants reporting lower NA-day when controlling for all other variables in the model.

Section 7: Sensitivity Analyses for Cross-day Associations:

Randomized condition effects. We also tested randomized condition (i.e., MM vs. LKM) as (a) a main effect, (b) an interaction effect with the mean-centered predictor variable, and (c) an interaction effect with the average level of the predictor variable. No condition main or interactions effects emerged, and the sign and significance of other predictors did not change when the outcome was next-day fruit and vegetable intake. Likewise, no condition main or interactions effects emerged, and the sign and significance of other predictors did not change when the outcome was today's NA-day and the predictor was yesterday's number of alcoholic drinks.

In many of the remaining models, only the interaction of condition with the average level of the predictor could be tested (i.e., we could not test within-person interactions) due to problems with model convergence. In most models, no significant condition effects or changes in the sign or significance of other predictors emerged. However, the negative within-person effect of yesterday's number of alcoholic drinks on today's (lower) PA-day was no longer significant (*b* = -.01, 95%CI [-.02, .00], *SE* = .01, β = -.01, *p* = .15), and the negative between-person relationship between NA-day during meditation and time spent meditating was no longer significant (*b* = -.20, 95%CI [-.55, .06], *SE* = .18, β = -.07, *p* = .25). Finally, model convergence could not be reached with any condition effects in which yesterday's PA-behaviour for physical activity predicted today's physical activity.

Inclusion of covariates. The sign and significance of the effects for each health behaviour did not change with addition of the covariates of sex, age, ethnicity, BMI, or CRP, again, except in the models in which yesterday's meditation predicted today's PA-day, yesterday's NA-behaviour for meditation predicted today's time spent meditating, and in which yesterday's alcohol use predicted today's PA-day. Specifically, the negative within-person relationship between yesterday's number of alcoholic drinks and today's (lower) PA-day was no longer significant (*b* = -.01, 95%CI [-.02, .00], *SE* = .01, β = -.01, *p* = .11) and the negative between-person relationship between average NA-behaviour for meditation and time spent meditating was no longer significant. In models in which yesterday's PA-day or NA-day, or PA-behaviour for physical activity predicted today's physical activity, men were more likely to spend more time active (*b* = .08 - .12, *SE* = .04 - .06, *p* = .01 - .02). When yesterday's NA-behaviour for physical activity predicted today's physical activity, those with a higher BMI were more likely to spend less time active (*b* = -.01, 95%CI [-.02, -.002], *SE* = .00, β = -.06, *p* = .01). In models in which yesterday's PA-behaviour or NA-behaviour for fruit and vegetable intake predicted the amount of fruits and vegetables consumed today, older participants were significantly more likely to eat larger amounts of fruits and vegetables (*b* = .03-.05, *SE* = .01-.02, β = .34-.40, all *ps* = .01). Diverging from the sensitivity analyses on the same-day relationships, when today's NA-day was the outcome and fruit and vegetable intake was the predictor, white participants were more likely to experience more intense NA-day (*b* = .11, 95%CI [.003, .21], *SE* = .05, β = .05, *p* = .04). In the model in which yesterday's NA-behaviour for meditation predicted today's time spent meditating, we found that men (*b* = .25, 95%CI [.04, .46], *SE* = .11, β = .12, *p* = .02) and older participants (*b* = .01, 95%CI [.001, .03], *SE* = .01, β = .12, *p* = .02) were more likely to spend more time meditating whereas white participants (*b* = -.29, 95%CI [-.53, -.05], *SE* = .12, β =- .12, *p* = .02) were more likely to spend less time meditating. We no longer observed an autoregressive effect of alcohol use when PA-behaviour for alcohol use yesterday predicted alcohol use today (*b* = .07, 95%CI [-.00, .14], *SE* = .04, *p* = .06), and in this model, as well as in the model in which NA-behaviour for alcohol use yesterday predicted alcohol use today, we found that men were more likely to consume greater amounts of alcohol (*b* = .39-.60, *SE* = .18-.24, β(NE model) = .19, *p = .02-.03*) than women. Some βs were not obtained due to convergence issues, and the effect of covariates on the relationship between physical activity and PA-behaviour for physical activity yesterday could not be tested due to convergence issues.

Table S1. Lagged associations predicting today's daily positive affect from yesterday's health behaviours.

	Fixed Effects		
	b	*β*	*95% CI*
Intercept	1.53**	1.82	[1.39,1.68]
Phy_C_{t-1}	-.00	-.00	[-.03,.02]
Phy_Avg	.65**	.17	[.32,0.98]
$Emotions_{t-1}$	.20**	.09	[.17,.23]
Time	.02**	.04	[.01,.02]
-2LL	12986.08		
	b	*β*	*95% CI*
Intercept	1.21**	1.82	[1.02,1.41]
FVI_C_{t-1}	.01*	.01	[.00,.02]
FVI_Avg	.13**	.26	[.10,.17]
$Emotions_{t-1}$	.19**	.09	[.17,.22]
Time	.01**	.03	[.01,.02]
-2LL	13297.09		
	b	*β*	*95% CI*
Intercept	1.54**	1.82	[1.35,1.74]
Med_C_{t-1}	.00	.01	[-.00,.01]
Med_Avg	.15*	.10	[.03,.26]
$Emotions_{t-1}$	.19**	.09	[.16,.22]
Time	.02**	.04	[.01,.02]
-2LL	13061.99		

	b	β	*95% CI*
Intercept	1.76**	1.81	[1.65,1.88]
Alc_C_{t-1}	-.01**	-.01	[-.02,.00]
Alc_Avg	-.01	-.01	[-.11,.09]
$Emotions_{t-1}$	.20**	.09	[.17,.22]
Time	.01**	.04	[.01,.02]
-2LL	13433.11		

Note. -2LL = -2 x ln(model likelihood), a.k.a. model deviance. Phy = physical activity; FVI = fruit and vegetable intake; Med = meditation; Alc = alcohol consumption. *_C indicates person mean-centered variable, or within-person effects. *_Avg indicates individual means of variable, or between-person effects. *_t indicates today. *_t-1 indicates yesterday. Phy_C_{t-1} and Phy_Avg divided by 100 to allow for convergence. Med_C_{t-1} and Med_Avg divided by 10 to allow for convergence. ** $p < .01$. * $p < .05$.

Table S2. Lagged associations predicting today's health behaviours from yesterday's daily positive affect.

	Fixed Effects							
	Physical Activity$_t$				Fruit and Vegetable Intake$_t$			
	b	*β*	*95% CI*	*p*	*b*	*β*	*95% CI*	*p*
Intercept	.16**	.34	[.06,.25]	<.001	2.28**	4.19	[1.59,2.97]	<.001
Behavior_C$_{t-1}$	.09**	.04	[.05,.12]	<.001	.19**	.25	[.16,.21]	<.001
PA-day_C$_{t-1}$	.01	.01	[-.01,.03]	.16	-.01	-.01	[-.08,.06]	.75
PA-day_Avg	.10**	.07	[.05,.15]	<.001	1.01**	.70	[.66,1.37]	<.001
Time					.02	.04	[-.00,.04]	.07
-2LL	10450.76				33261.98			

Note. -2LL = -2 x ln(model likelihood), a.k.a. model deviance. PA-day = daily positive affect. *_C indicates person mean-centered variable, or within-person effects. *_Avg indicates individual means of variable, or between-person effects. Physical Activity$_{t-1}$ and Physical Activity$_t$ divided by 100 to allow for convergence. Models including meditation and alcohol use were not included because they did not converge. ** $p < .01$. * $p < .05$.

Table S3. Lagged associations predicting today's health behaviours from yesterday's positive affect felt during each health behaviour.

	Fixed Effects			
	Health Behavior			
	b	*β*	*95% CI*	*p*
Intercept	.22**		[.10,.35]	<.001
Phy_C	.03		[-.01, .08]	.17
PA-beh_Phy_C	.00		[-.02,.03]	.88
PA-beh_Phy_Avg	.06*		[.01,.10]	.01
-2LL	4744.45			
	b	*β*	*95% CI*	
Intercept	2.73**	4.22	[2.06,3.40]	<.001
FVI_C	.22**	.29	[.22,.26]	<.001
PA-beh_FVI_C	.12**	.06	[.05,.20]	.002
PA-beh_FVI_Avg	.59**	.60	[.34,.83]	<.001
-2LL	31800.92			
	b	*β*	*95% CI*	
Intercept	.99**	.92	[.55,1.43]	<.001
ALC_C	.07*	.08	[.00, .14]	.04
PA-beh_Alc_C	.04	.02	[-.05,.13]	.35
PA-beh_Alc_Avg	-.05	-.04	[-.23,.13]	.60
-2LL	9821.91			

Note. -2LL = -2 x ln(model likelihood), a.k.a. model deviance. Phy = physical activity; FVI = fruit and vegetable intake; Alc = alcohol consumption. PA-beh_* indicates positive affect during the given health behavior. *_C indicates person mean-centered variable, or within-person effects. *_Avg indicates individual means of variable, or between-person effects. Physical Activity is divided by 100 to allow for convergence. β*s* could not be obtained in the physical activity model due to convergence issues. Meditation model not included due to convergence issues. ** $p < .01$. * $p < .05$.

Table S4. Same-day associations between daily negative affect and health behaviours.

	Fixed Effects			
	b	*β*	*95% CI*	*p*
Intercept	.45**	.47	[.38,.53]	<.001
Phy_C	-.04**	-.02	[-.07,-.02]	<.001
Phy_Avg	.07	.02	[-.11,.26]	.41
Time				
-2LL	8372.52			
	b	*β*	*95% CI*	
Intercept	.54**	.47	[.43,.65]	<.001
FVI_C	-.01	-.01	[-.02,.00]	.10
FVI_Avg	-.01	-.03	[-.04,.01]	.22
Time				
-2LL	8510.42			
	b	*β*	*95% CI*	
Intercept	.54**	.48	[.44,.65]	<.001
Med_C	-.00	-.00	[-.00,-.01]	.51
Med_Avg	-.05	-.03	[-.11,.02]	.16
Time				
-2LL	8428.42			
	b	*β*	*95% CI*	
Intercept	.46**	.47	[.40,.52]	<.001
Alc_C	-.01	-.01	[-.02,.00]	.21

Alc_Avg	.02	.02	[-.03,.07]	.44
Time				
-2LL	8656.31			

Note. Phy = physical activity; FVI = fruit and vegetable intake; Med = meditation; Alc = alcohol consumption. *_C indicates person mean-centered variable, or within-person effects. *_Avg indicates individual means of variable, or between-person effects.

Table S5. Lagged associations predicting today's daily negative affect from yesterday's health behaviours.

	Fixed Effects			
	b	*β*	*95% CI*	*p*
Intercept	.43**	.48	[.35,.50]	<.001
Phy_C_{t-1}	.00	.00	[-.02,.02]	.99
Phy_Avg	.15	.04	[-.02,.31]	.08
$Emotions_{t-1}$	-.05**	-.02	[-.07,-.03]	<.001
Time				
-2LL	8222.58			
	b	*β*	*95% CI*	
Intercept	.52**	.48	[.42,.62]	<.001
FVI_C_{t-1}	.00	.00	[-.01,.01]	.83
FVI_Avg	-.01	-.02	[-.03,.01]	.35
$Emotions_{t-1}$	-.05**	-.02	[-.07,-.02]	<.001
Time				
-2LL	8322.12			
	b	*β*	*95% CI*	
Intercept	.51**	.48	[.42,.61]	<.001
Med_C_{t-1}	-.01	-.01	[-.01,.00]	.13

Med_Avg	-.03	-.02	[-.08,.03]	.39
$Emotions_{t-1}$	-.05**	-.02	[-.07,-.02]	<.001
Time				
-2LL	8143.48			
	b	*β*	*95% CI*	
Intercept	0.47**	.48	[.42,.53]	<.001
Alc_C_{t-1}	.02*	.01	[.00,.03]	.01
Alc_Avg	.00	.00	[-.04,.05]	.91
$Emotions_{t-1}$	-0.05**	-.02	[-.08,-.03]	<.001
Time				
-2LL	8341.53			

Note. -2LL = -2 x ln(model likelihood), a.k.a. model deviance. Phy = physical activity; FVI = fruit and vegetable intake; Med = meditation; Alc = alcohol consumption. *_C indicates person mean-centered variable, or within-person effects. *_Avg indicates individual means of variable, or between-person effects. *_t indicates today. *_t-1 indicates yesterday. PA_C_{t-1} and PA_Avg divided by 100 to allow for convergence. Med_C_{t-1} and Med_Avg divided by 10 to allow for convergence. ** $p < .01$. * $p < .05$.

Table S6. Lagged associations predicting today's health behaviours from yesterday's daily negative affect.

	Fixed Effects							
	Physical Activity$_t$				Fruit and Vegetable Intake$_t$			
	b	*β*	*95% CI*		*b*	*β*	*95% CI*	
Intercept	.32**	.34	[.26,.38]	<.001	4.35**	4.19	[3.90,4.80]	<.001
Behaviour_C$_{t-1}$	.09**	.03	[.06,.12]	<.001	.19**	.25	[.16,.21]	<.001
NA-day_C$_{t-1}$	.01	.01	[-.01,.14]	.19	-.01	-.01	[-.08,.06]	.76
NA-day_Avg	.04	.01	[-.06,.14]	.40	-.51	-.18	[-1.25,0.23]	.18
Time					.02	.04	[-.00,.04]	.07
-2LL	10464.29				33287.96			

Note. -2LL = -2 x ln(model likelihood), a.k.a. model deviance. NA-day = daily negative affect. *_C indicates person mean-centered variable, or within-person effects. *_Avg indicates individual means of variable, or between-person effects. Physical Activity$_{t-1}$ and Physical Activity$_t$ divided by 100 to allow for convergence. Models including meditation and alcohol use were not included because they did not converge. ** $p < .01$. * $p < .05$.

Table S7. Lagged associations predicting today's health behaviours from yesterday's negative affect felt during each health behaviour

	Fixed Effects			
	Health Behaviour			
	b	*β*	*95% CI*	*p*
Intercept	.39**	.37	[0.34,.43]	<.001
Phy_C	.03	.02	[-.01, .08]	.11
NA-beh_Phy_C	-.02	-.01	[-.07,.03]	.43
NA-beh_Phy_Avg	-.06	.02	[-.15,.03]	.23
-2LL	4717.28			
	b	*β*	*95% CI*	
Intercept	4.19**	4.22	[3.89,4.49]	<.001
FVI_C	.24**	.31	[.20,.27]	<.001
NA-beh_FVI_C	-.04	-.01	[-.17,.08]	.53
NA-beh_FVI_Avg	.09	.02	[-.85,1.02]	.85
-2LL	31879.88			
	b	*β*	*95% CI*	
Intercept	1.63**	1.59	[1.51,1.76]	<.001
MED_C	.08**	0.08	[0.03, 0.13]	.001
NA-beh_Med_C	-.01	-0.01	[-0.09,0.06]	.70
NA-beh_Med_Avg	-.31*	0.11	[-0.57,-0.06]	.02
-2LL	19652.16			

	b	*β*	*95% CI*	
Intercept	.69**	.94	[.48,.90]	<.001
ALC_C	.07	.08	[-.00, .14]	.05
NA-beh_Alc_C	-.01	-.00	[-.13,.12]	.89
NA-beh_Alc_Avg	.70**	.32	[.34,1.06]	<.001
-2LL	9792.44			

Note. -2LL = -2 x ln(model likelihood), a.k.a. model deviance. Phy = physical activity; FVI = fruit and vegetable intake; AlC = alcohol consumption. NA-beh_* indicates negative affect during the given health behaviour. *_C indicates person mean-centered variable, or within-person effects. *_Avg indicates individual means of variable, or between-person effects. Physical Activity is divided by 100 to allow for convergence. ** $p < .01$. * $p < .05$.