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Effects of mindfulness training on daily stress response in college students: Ecological momentary assessment of a randomized controlled trial

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Abstract

Objective: Mindfulness training has been shown to reduce rates of depression, anxiety and perceived stress, but its impact on stress and emotion regulation in real-world settings in the college-aged population is unknown. This study examines the effect of an 8-session long mindfulness training on first-year college students' daily experiences of stress and emotion regulation.

Methods: Fifty-two first-year students were randomized to the mindfulness training or the waitlist-control group during the fall academic semester. Before, during and after the trial, students completed 10-days of ecological momentary assessments (EMA), reporting on family and school or work stress, negative emotion, rumination, and interference by unwanted thoughts and emotions

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Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the Pennsylvania State University's institutional review board and with the 1964 Helsinki declaration and its later amendments.

Research involving human participants and/or animals. Study procedures have been approved by the university ethics committee and have therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments

Informed consent: Informed consent was obtained from all participants included in the study

up to four times a day. Multilevel regression analysis compared levels of momentary stress and emotion regulation difficulties, as well as the strength of the moment-level association between stress and emotion regulation, by intervention condition, before, during and after the trial.

Results: Controls showed an exacerbation of family stress related negative emotion, rumination and interference, across the fall semester. However, intervention youth showed stable levels of emotion regulation responses to family stress across the semester. Emotion regulation responses to school or work stress did not differ by intervention condition.

Conclusions: Mindfulness training helps to prevent the depletion of emotion regulation capacity in this sample of relatively healthy first-year college students. EMAs allow the assessment of emotion regulation in the context of naturally occurring stress, and enhances the specificity and external validity of evaluations of psychological interventions.

Keywords

mindfulness intervention; transition to college; ecological momentary assessment; family conflict; emotion regulation

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The transition to college can be a time of heightened vulnerability to stress, as students must quickly acclimate to an unfamiliar environment, take on greater level of personal responsibility, and manage new academic expectations. One third of first-year college students worldwide and in the United States report past-year history of one or more mental health disorders, and first-year students frequently endorse high levels of interpersonal and academic stress (Acharya et al., 2018; American College Health Association, 2014; Auerbach et al., 2018; Misra & McKean, 2000; Towbes & Cohen, 1996). Furthermore, decreased level of parental monitoring and increased access to substances including alcohol, marijuana and prescription stimulants make this age group especially susceptible to coping with stress using maladaptive behaviors such as substance use and poor sleep hygiene (Arria et al., 2008; Hoeppner et al., 2012; Kenney et al., 2014; Van Reen et al., 2016). These coping behaviors only exacerbate stress and risk for mental health problems. Prevention strategies that can effectively permeate the daily lives of college students to promote healthy coping and prevent the onset or exacerbation of mental health disorders are needed on university campuses.

A growing body of research points to universal mindfulness training as a promising strategy for the prevention of mental health problems in college students (Halladay et al., 2019). Defined as the practice of observing and accepting present thoughts, feelings and bodily sensations without judgment (Kabat- Zinn, 2003), mindfulness training effectively reduces levels of depression, anxiety and perceived stress in college and graduate students (Breedvelt et al., 2019; Dvořáková et al., 2017; Halladay et al., 2019). However, more research on its effect outside of intervention and assessment sessions can help reveal the mechanisms that contribute to change.

Mindfulness-based interventions have been shown to reduce level of perceived stress (Halladay et al., 2019). However, first-year college students experience a variety of stressors, and examining intervention effects on different types of stressors can improve our understanding of the intervention’s specificity and generalizability (Dvořáková et al., 2019).

For first-year college students, interventions that effectively target responses to school-related problems is especially important. The primary goal of college is educational, and yet many students report poorer academic adjustment across the transition from high school to college (Larose et al., 2019). Mindfulness is associated with improved academic performance among students in primary and secondary schools (Bakosh et al., 2016; Franco et al., 2010, López-González et al., 2016). However, evidence for the effect of mindfulness-based interventions on academic functioning in post-secondary schools is limited, with only one study reporting improved grades (Bennett & Dorjee, 2016), and another reporting reduced test anxiety in undergraduate and graduate students (Dundas et al., 2016). Less is known about the effect of mindfulness training on daily occupational stress for college-aged youth, defined as the extent to which students were bothered or stressed by problems at school or work.

In addition to increased academic demands, the transition to college is accompanied by disruptions in the family system as students gain new levels of autonomy (Baete Kenyon & Silverberg Koerner, 2009). Still, these youth remain digitally connected with family members, and the family continues to be a salient source of stress in first-year college students (Hofer, 2008; Johnson et al., 2010; Mattanah et al., 2011). In fact, a survey of college students in the US identified “pressure to do well in school/parental expectations” as the most frequently endorsed life stressor and “tests” as the most frequently endorsed daily hassle (Bland et al., 2012). In addition to developmentally normative shifts in the parent-youth relationship during the student’s transition to college, such added pressures may contribute to increased levels of conflict between the youth and their family members, and poorer adjustment to college. However, no study has examined the effects of mindfulness on college students’ management of family stress, operationalized as the extent to which a student feels bothered or stressed by an argument or disagreement with parents or family members.

Mindfulness practice leads to improvement in health and well-being, through its effects on emotion regulation, including decreases in levels of rumination (i.e., negative thinking), negative emotions, and emotional reactivity, or the extent to which one experiences distress in the face of a negative event (Davidson, 2016; Finkelstein-Fox et al., 2019; Gu et al., 2015; Roemer et al., 2015). Mindfulness practice is also linked to increased psychological flexibility, defined as the ability to adapt and balance various psychological demands and still take action in a value-consistent manner (Fledderus et al., 2010; Kashdan & Rottenberg, 2010). Evaluations of mindfulness training on emotion regulation often rely on self-report questionnaires that are conducted before and after the intervention (Fledderus et al., 2010; Robins et al., 2012). While useful for capturing self-perceptions of emotion regulation, questionnaires do not proximally measure actual emotion regulation processes in response to specific and meaningful stimuli. Objective measurements conducted in laboratory studies address this gap (Davidson & Kaszniak, 2015); however, they cannot detect intervention effects in unstandardized environments. As mindfulness is considered a moment-by-moment practice (Kabat- Zinn, 2003), rigorous evaluations of mindfulness training may benefit from an assessment of stress and emotion regulation in the context of daily life.

These methodological limitations can be overcome with intensive longitudinal measures of momentary experiences, including daily diaries and ecological momentary assessments (EMA; Schneider & Stone, 2016). Dispositional mindfulness is associated with better psychological functioning in daily life, including lower levels of negative affect, higher levels of positive affect, lower levels of affective reactivity to stress and greater use of adaptive coping skills as reported on EMAs (Dixon & Overall, 2016; Keng & Tong, 2016; Spears et al., 2019). Offering greater external validity, EMAs can usefully assess how interventions can affect daily experiences and influence psychological processes that unfold over time (Heron et al., 2017; Sliwinski, 2008). Specifically, EMAs can examine how interventions affect the link between a stimuli and response, such as the momentary link between stress and rumination, in daily life.

Despite its utility, there are only a few published studies that have employed this methodology in an RCT of mindfulness training. All focus on adult samples. Mindfulness training was associated with lower levels of negative affect in the daily lives of older adults with anxiety-related distress and cognitive dysfunction, adult smokers, and older adults with high levels of perceived stress (Moore et al., 2016; Oken et al., 2014; Ruscio et al., 2016), as well as decreases in daily ADHD symptoms in adults with ADHD (Mitchell et al., 2017). Moreover, mindfulness was associated with a reduction in pain-related catastrophizing, morning disability and fatigue, and stress-related anxious mood among 143 21- to 81-year-old adults with rheumatoid arthritis (Davis et al., 2015). Likewise, 130 depressed middle-aged adults assigned to the mindfulness condition experienced more positive emotions when they participated in pleasant activities in the day-to-day, than did those in the waitlist condition (Geschwind et al., 2011). These studies demonstrate that mindfulness training can alter mean levels of affect, as well as emotion regulation in daily life; however, this assessment strategy has not been used to evaluate mindfulness training as a prevention strategy in relatively healthy samples. Moreover, because assessments were often conducted only before and after the trial, it is unclear when mindfulness training begins to take effect. A three-burst design wherein EMAs are completed before, during and after the trial can help to detect when participants respond to the intervention and help to further tailor sessions to augment treatment response.

The current RCT examined the effects of an 8-session long mindfulness training on first-year college students' daily psychosocial experiences, to better capture how gains associated with this prevention intervention generalize to the daily life context. We first tested the effect of the intervention on levels of momentary family and occupational stress and three facets of emotion regulation: negative emotion, rumination and interference, an aspect of psychological flexibility defined as the extent to which thoughts and feelings interfere with activities and plans. We hypothesized that the intervention participants would report lower levels of stress, negative emotion, rumination, and interference at post intervention. Second, we tested intervention effects on momentary emotion regulation *in response* to stress from family conflict and occupational problems. We hypothesized that mindfulness training would increase participants' abilities to cope with daily family and occupational stress.

Method

Participants

Participants were 52 first-year college students 18 or 19 years old, attending a large public university in northeast United States. During the first three weeks of the university's fall semester, from August to September 2014, students were recruited to participate in a mindfulness program for stress management, via emails distributed through Residential Life Services and Honor's College contact lists, flyers, and information booths at first-year involvement fairs. Eligible students were first-years living in on-campus residence halls. Eligibility screenings were sent by email, and the 144 students who completed the screenings were all eligible. Of these, 109 provided informed consent and were enrolled in the larger RCT. See primary outcome paper by Dvořáková et al. (2017) for a full CONSORT diagram.

The current study focuses on a subset of RCT participants who were randomized to complete EMAs during the study. The 52 participants in the current study who completed any EMAs were majority 18 years old (83%), female (65%), and Caucasian (56%). Other race/ethnicities represented included 22% Asian, 4% African American, 8% Hispanic, and 10% mixed race. Twelve percent of participants identified as an international student. Highest level of participant-reported maternal education was 15% high school graduation or less, 25% some college or 2-year college graduation, 33% 4-year college graduation, 23% graduate degree and 4% unknown. Likewise, family income levels were diverse: 8% < $20,000, 19% $20,00049,000, 19% $50,000–99,000, 23% $100,000–199,999, 10% > $200,000 and 20% unknown. Out of 52 participants, 12% endorsed therapy or counseling during the past 6 months. Twenty-nine percent (n=15) reported any experience with mindfulness or meditation practices, including mindfulness, vipassana meditation, zen meditation and guided visualization. Of the 15, one reported that they engaged in this practice weekly, three reported practicing one to three times a month, and 11, less than once a month. At pre-intervention, 13 and 14 participants had scores that exceeded clinical cut-offs on the GAD-7 (≥ 10) and the PHQ-8 (≥ 10), respectively (Kroenke et al., 2009; Spitzer et al., 2006).

Procedures

Randomization—The larger RCT employed a 2 × 2 factorial design: 109 consented participants were stratified by gender, randomized to mindfulness training (n=55) or waitlist control (n=54; using https://www.randomizer.org), and informed of their intervention condition over email. See Dvořáková et al. (2017) for more details on enrollment and randomization. Within each condition, 50% participants were further randomized to complete EMAs before (Burst 1), during (Burst 2) and after (Burst 3) the trial. Out of the 55 participants who were assigned to complete EMAs, 52 (n=26 in each condition) completed any EMAs across the three bursts. For each burst, participants received $15 for completing 85% of EMAs. They received additional $5 for each 5% increase in completion rate for a total of $30 per burst. Study procedures were approved by the university's institutional review board.

Ecological momentary assessments.—Participants in the current analysis (n=52) were instructed to complete three bursts of EMAs. Spaced 21 days apart from one start date to the next, each burst started on a Monday and lasted 10 days. For each burst, participants received research smartphones with the study assessment application that was designed by the university's Survey Research Center. The first burst began on September 29, 2014, prior to the start of the intervention, the second burst on October 20, 2014, on week three of the six week-long intervention, and the third burst on November 10, 2014 after the completion of the intervention. Each day, participants completed up to four momentary assessments, immediately in response to pseudo-random survey prompts delivered to the participants' research smartphones between 8:00AM – 11:59AM, 12:00PM – 3:59PM, 4:00PM – 7:59PM and 8:00PM – 12:00AM. Each participant could complete up to 120 total (4 moments/day × 10 days/burst × 3 bursts). Across the three bursts, the average compliance rate was 55.4% (*SD*=18.2, *Range*=14.0–83.0). Participants completed mean 27 EMAs (*SD*=6.3, *Range*=7–35) at Burst 1, 22 (*SD*=8.4, *Range*=0–33) at Burst 2, and 18 (*SD*=9.8, *Range*=0–35) at Burst 3.

Intervention.—Participants randomized to the mindfulness training condition participated in an 8-session long Just Breathe program (Dvořáková et al., 2017) which was an adaptation for the college population of the Learning 2 Breathe program (Broderick, 2013). The goal of the mindfulness-training program was to enhance emotion regulation in students (Broderick, 2013; Dvořáková et al., 2017), with group sessions that focused on the following themes: body awareness, thought awareness, emotion awareness, integration of body, thought and emotion awareness, reduction of self-judgements, and integration of mindfulness practice in daily life. For more details about the intervention, see publications by Dvořáková et al. (2017) and Broderick (2013). The eight 80-minute long group sessions were delivered by one lead and one assistant facilitator over a period of 6 weeks (2 sessions/week during weeks 1 and 2, 1 session/week during weeks 3 to 6) in the evenings in the dormitories. Each group consisted of 20 to 25 students. Among intervention participants in the larger RCT, the average number of sessions attended was 5.2 (*SD*=2.7, *Range*=0–8); 60% of the intervention group attended 6 or more sessions and only 14% attended no sessions due to course conflicts (Dvořáková et al., 2017). Facilitators provided access to audio recordings of guided meditations, instructed participants to practice skills at home, and encouraged them to remind themselves of their intention to practice mindfulness daily outside of the sessions. Participants tracked and submitted logs of their mindfulness practice each week. Logs were tailored to session content.

Measures

Family and occupational stress.—Stress from family conflict and school or work (i.e., occupational) problems during the past hour were assessed with two single items on a scale of 0 (not at all) to 100 (very much). Adapted from the Daily Inventory of Stressful Events (DISE; Almeida et al., 2002), items asked "In the last hour, to what extent were you bothered or stressed by… an argument or disagreement with parents or family members" and "… problems at school or work," to assess family and occupational stress, respectively. DISE is a well validated and frequently used measure of daily stress (i.e., family, school, discrimination). Previous research using intensive longitudinal methodology has used single

items successfully to assess specific domains of daily stress (Almeida et al., 1999; Chung et al., 2009).

Negative emotion.—Three items rated on a 0 (not at all) to 100 (very much) scale assessed the extent to which participants felt “sad,” “nervous,” or “angry,” at the time of the assessment. Emotions were selected to represent both high and low activated emotions. Correlations among items at the between-person level of analysis were high (r =.72–.80, p<.001). Correlations and person-centered level of each item were .24 (nervous & angry), .33 (nervous & sad), .53 (sad & angry); p < .001 for all pairwise correlations.

Rumination—since the last hour was assessed with two items from the rumination subscale of the Rumination and Reflection Questionnaire (RRQ) (Trapnell & Campbell, 1999). Participants endorsed the extent to which “I dwelled for a long time over things that happened to me” and “In my mind, I often played back how I acted in a past situation” since the last hour, on a 0 (not at all) to 100 (very much) scale. The two items were highly correlated at the between-person (r=.94, p<.001) and within-person (r=.61, p<.001) levels of analysis. The RRQ has strong psychometric properties, including high reliability, and convergent and divergent validity (Trapnell & Campbell, 1999).

Interference—since the last hour was measured with a single item adapted from the long and short versions of the psychometrically validated Avoidance and Fusion Questionnaire which measures psychological flexibility (Greco et al., 2008): “My thoughts and feelings interfered with my activities/plans,” rated on a 0 (not at all) to 100 (very much scale).

Data Analysis

Prior to data analysis, all dependent variables at the moment level were square root transformed to reduce the positive skew. The first aim of the study was to test the effect of the intervention on moment levels of family and occupational stress, negative emotion, rumination and interference. Data were nested into four levels: momentary assessments, nested in days, nested in bursts, nested in participants. To account for the multiple levels in the data, we conducted four-level linear regressions (PROC Mixed in SAS 9.4 software), examining each of the five moment-level variables as outcomes in separate models. Models included random intercepts at the day, burst and person levels, as well as first-order autoregressive covariance structure for the residuals to account for time dependencies between adjacent momentary assessments completed within the same day. Primary predictors were intervention condition (control=0, intervention=1), burst (dummy coded, Burst 1=0), and the intervention × burst interaction terms. A significant intervention × burst interaction suggested that levels differed by condition and burst. We also controlled for weekend or weekday status (weekday=0) and day in burst, because levels of stress, negative emotion, rumination and interference may systematically change over the 10-day course. Past 6-month history of therapy or counseling (effect coded, no therapy=−1, therapy=1), and gender (effect coded, female=−1, male=1) were also included as controls, consistent with the primary outcome paper (Dvořáková et al., 2017).

Second, we tested intervention effects on *responses* to stress. Specifically, we examined whether intervention condition and burst significantly moderated the hypothesized concurrent links between two types of stressors and three indicators of emotion regulation response. Dependent variables were square root transformed levels of negative emotion, rumination and interference at the moment level. Predictor variables were intervention condition, burst, and person-mean and person-centered levels of past hour stress (family and occupational); three-way interaction terms between person-centered stress, intervention condition and burst; and the associated two-way interaction terms. A significant three-way interaction term indicated that the slope of the concurrent association between stress and emotion regulation response differed across bursts, by intervention condition. Consistent with analyses described for Aim 1, models included random intercepts at the level of the days, bursts and persons, as well a first-order autoregressive covariance structure for the residuals. The three models examining occupational stress also included the random slope effects of occupational stress on the dependent variable at the day, burst, and person levels. The three models testing family stress included random slope effects of family stress only at the day and person levels, as the inclusion of a random slope at the burst level did not significantly improve the models ($X^2(2)<3.0$, $p>0.20$). Covariates were weekend or weekday status, day in burst, history of therapy or counseling and gender. Significant three-way interactions were probed to compare the simple slopes between intervention conditions and bursts.

Results

Randomization and Retention

The 55 participants assigned to complete EMAs during the RCT did not differ from the rest of the sample ($n=54$), with respect to demographic variables, past 6-month therapy history, and baseline levels of anxiety, depression and satisfaction with life. Among the 55 participants assigned to EMAs, those in the intervention group ($n=28$) were more likely to endorse past 6-month history of therapy or counseling than those in the waitlist control group ($n=27$; $X^2(1)=5.02$, $p=.025$). However, the two intervention conditions did not differ by demographic characteristics or baseline levels of anxiety, depression and satisfaction with life.

Three participants in the EMA condition did not complete any EMAs, resulting in the current analytical sample of 52 participants. Out of the 52 who completed any EMAs at Burst 1 (pre-intervention), four participants did not complete any at Bursts 2 (during intervention) or 3 (post-intervention), and three participants did not complete any EMAs at Burst 3. EMA data were available for all three bursts from 45 participants (81% of those assigned to this assessment). Those who did not complete EMAs at all three bursts ($n=10$) did not differ from the 45 participants who completed some EMAs during all three bursts, with respect to demographic or pre-intervention clinical characteristics.

Stress and Emotion Regulation

Given the multiple time scales across which assessments occurred, we first examined intraclass correlations (ICC) for each measure, which provides an estimate of the reliability

of ratings within individuals and the distribution of variance for each variable (See *Figure* 1). For each of the five variables, ICC ranged from .27 to .41, suggesting that between-person differences contributed 27% to 41% of its variance. Variance in family stress was least attributable to person-level factors. Proportion of variance attributable to burst-level characteristics, such as pre, during and post intervention status, ranged from 27% to 31%. About 20% of the variables' variances were likely due to differences between days. Lastly, 10% to 24% of variability were attributable to differences between moments. Notably, a greater proportion of stress from family conflict (24%) was attributable to moment-to-moment differences, in comparison to occupational stress (10%), suggesting that the level of occupational stress from one moment to the next does not vary as much as it does for family stress.

Next, we described levels of family and occupational stress, negative emotion, rumination and interference by intervention condition and burst (Table 1). Descriptively, participants in the intervention condition appeared to have somewhat higher levels of family and occupational stress, and experience more negative emotion, rumination and interference. However, four-level regressions testing effects of condition and burst, accounting for covariates and random intercepts at the day, burst and person levels, suggested that mean levels did not statistically differ between conditions and bursts.

Emotion Regulation Responses to Stress

Next, we evaluated the effect of the intervention on concurrent moment-level associations between the two types of stress (i.e., family and occupational) and three emotion regulation responses (i.e., negative emotion, rumination, and interference) in six separate models. A significant stress × intervention × burst interaction signified that the participant response to stress differed by intervention condition and burst. As shown in Table 2, participants who reported higher levels of family stress on average also reported higher levels of negative emotion and interference; the between-person association between family stress and rumination escaped statistical significance (p=.055). More importantly, all participants reported more negative emotion, rumination and interference when they experienced greater than usual levels of family stress (Table 2), but the strength of these concurrent moment-level associations varied by intervention condition and burst.

As shown in the *Δ Intv – Control* column of Table 3 and in Figure 2 Panel A, the association between family stress and negative emotion was weaker among intervention participants than controls at Burst 3 (ΔB=−0.03, *95% CI* [−0.06, −0.00]; $f^{2=}$0.43). Intervention and control participants did not show a net change in slope from Burst 1 (pre) to 3 (post). Likewise, all participants reported greater levels of rumination when experiencing higher levels of family stress, but intervention participants, much less so than controls at Burst 3 (ΔB=−0.04, *95% CI* [0.07, −0.01]; $f^{2=}$0.77). As shown in Table 3 and Figure 2 Panel B, control youth showed greater levels of rumination concomitant with family stress at Burst 3, relative to Burst 2. Whereas control participants had a statistically significant net increase from pre to post intervention (ΔB=0.04, *95% CI* [0.02, 0.06]), intervention participants did not experience this net increase. Consistent with negative emotion and rumination, all participants reported higher levels of interference in activities or plans when they

experienced higher than usual levels of family stress (see Table 3 and Figure 2 Panel C). Intervention participants experienced stress-related interference to a lesser extent in Burst 3, than controls (ΔB=−0.04, *95% CI* [−0.07, −0.00]; $f^{2=}$0.17). This may be due to a net increase in stress-related interference from Burst 1 to 3 among controls (ΔB=0.03, *95% CI* [0.01, 0.06]) but not among intervention participants.

We repeated the above described analysis for occupational stress. The three way interaction terms between occupational stress × intervention × burst did not significantly predict concurrent levels of negative emotion, rumination and interference. Therefore, we examined the moderating effect of burst (person-centered occupational stress × burst), controlling for person mean level of occupational stress, intervention condition, and covariates. All participants reported greater levels of negative emotion, rumination and interference when they reported higher than usual occupational stress. A significant stress × Burst 3 interaction term (B=0.01, *95% CI* [0.00, 0.02], p=.003) suggested that the link between occupational stress and negative emotion intensified from Burst 1 (B=0.02, *95% CI* [0.01, 0.03], p<.001) to Burst 3 (B=0.04, *95% CI* [0.03, 0.05], p<.001). However, associations with rumination (B=0.03, *95% CI* [0.02, 0.04], p<.001,) and interference (B=0.03, *95% CI* [0.02, 0.04], p<.001) were constant across the three bursts. Participants with higher mean levels of occupational stress over the course of the study reported higher levels of negative emotion (B=0.06, *95% CI* [0.04, 0.08], p<.001), rumination (B=0.08, *95% CI* [0.06, 0.10], p<.001) and interference (B=0.07, *95% CI* [0.08, 0.09], p<.001).

Discussion

This RCT found that mindfulness training helps to attenuate first-year college students' responses to family stress across the fall academic semester. All participants reported higher levels of negative emotion, rumination, and interference when they experienced higher than usual levels of family or occupational stress, reflecting emotional, cognitive and behavioral reactions to stress arising in daily life. While the control participants exhibited increasing levels of reactivity to family stress from early to late fall semester, participants in the mindfulness training condition showed relatively stable levels. EMAs can complement existing evaluation strategies and enhance our understanding of how intervention effects generalize to the management of stress in daily life outside of facilitated group sessions.

These findings have implications for clinical practice and research. The current study adds to a growing body of evidence supporting the use of mindfulness training as a universal prevention strategy for maintaining health and well-being, specifically emotion regulation, among college students. In comparison to the control condition, participants in the intervention condition reported lower levels of negative emotion, rumination and interference in response to family stress, during the post-intervention period (i.e., Burst 3). This effect was preventive as the group difference was driven by control participants experiencing *greater* difficulty with emotion regulation in response to family stress as the semester progressed, while the intervention youth showed stable associations across bursts. According to the strength model of self-regulation, individuals' capacities for self-regulation is limited and susceptible to depletion and renewal (Baumeister & Heatherton, 1996). This model is supported by neuroimaging studies of emotion regulation, which demonstrate that

individuals exhibit more emotion reactivity in the amygdala and weaker functional connectivity between the amygdala and the ventromedial prefrontal context in response to an unpleasant stimuli, when subjected to a difficult attention control task prior to the emotion regulation task (Wagner & Heatherton, 2012). For first-year college students, the challenges of the first academic semester likely requires tremendous effort and self-regulation. It is possible that while the depletion of self-regulation leads to more difficulty with emotion regulation in response to family stress, mindfulness training helped intervention participants maintain adequate self-regulation capacities (Friese et al., 2012). Consistent with the program aims, mindfulness training may be an effective strategy for the prevention of mental health problems in first-year university students, perhaps by preserving students' capacity to cope with provocative interpersonal stress, despite the demands of college.

Intervention effects were detected only in the context of family stress, and not in the context of school or work stress. Our descriptive findings and the situational context can help to disentangle this observation. Variance in family stress was least attributable to person-level factors. Rather, a greater proportion of family stress was due to moment-to-moment differences, in comparison to occupational stress. Whereas participants' interactions with their family members were likely episodic and time-limited, participants were constantly immersed in the school environment because everyone lived on campus. Accordingly, participants reported higher levels of stress from school or work problems, and likely experienced these problems as more pervasive than family conflict. In contrast, family stress may have been more volatile or unpredictable, leading it to have greater short-term impact on students but also be a more malleable target of intervention. Findings from a qualitative study of these participants corroborate current results. In focus groups and interviews, participants reported improved emotional awareness and family relationships, in addition to improved organization and time management (Mahfouz et al., 2018). For example, two students noted that they were able to control their automatic reactions to conflict with parents, and prevent the escalation of negative affect (Mahfouz et al., 2018). It is also possible that first-year students' immediate and short-term goals are more closely tied to their academic functioning rather than interpersonal matters. Valuing self-growth is particularly beneficial for the well-being of college-aged youth, whereas valuing community contributions is important for the well-being of middle-aged adults (Lekes et al., 2016). Although there are likely variations by culture and family upbringing, college students may perceive school and work problems as more consequential and have more difficulty applying skills gained in mindfulness training to these stressors.

The current study also has methodological implications for clinical science. A core tenet of mindfulness training is to observe in the moment without judgment (Kabat- Zinn, 2003). The integration of EMAs into the RCT allowed us to evaluate mindfulness training in a manner consistent with this unique feature, and examine intervention effects on the daily lives of its participants. We detected no intervention effects on the perceived experience of moment levels of stress, negative emotion, rumination and interference. Consistent with its core tenet, mindfulness training may not necessarily yield changes to the level of stress exposure or the baseline level of emotion regulation. Rather, mindfulness training more precisely affected emotion regulation in the context of naturally occurring stress in this non-clinical sample of relatively healthy youth. These findings have implications for technology-

assisted ecological momentary interventions that aim to inject skills and alternative coping strategies at precise moments of need (Nahum-Shani et al., 2017). For example, future work may test the effect of delivering brief interventions when youth experience greater than usual level of family stress. Moreover, students may particularly benefit from ecological momentary interventions designed to address school and academic stress.

Capitalizing on the study's three-burst design, we detected intervention effects after but not during the trial. Mindfulness may require repeated practice before its positive effects generalize to the daily lives its practitioners. In addition, practicing mindfulness may strengthen self-regulation resources and better prepare students for stress and work demands that accumulate with the progression of the academic semester. Intensive longitudinal methods, such as EMAs may complement traditional evaluation strategies by providing information on how and when the intervention generalizes to daily life.

Limitations and Future Research Directions

Findings must be interpreted in the context of several limitations. First our sample is small and relatively homogenous, selected from one university campus. Moreover, the study was conducted during the fall semester, and findings may have been influenced by notable events on the academic calendar, including a week-long academic break that immediately followed Burst 2 data collection. Effects of mindfulness training may differ across university campuses and the time of intervention delivery, given the variability in campus culture and student body makeup. Second, although we were able to capitalize on the availability of many measurement occasions, levels of perceived family stress were quite low. Despite its low rates, responses to family stress appeared to be a malleable target of mindfulness training in this intervention. Third, we relied on self-reports. As such, the concurrent associations between stress and negative emotion, rumination or interference may be inflated by state-dependent recall. Use of objective ecological data, such as voice or movement data, can enrich subjective data and augment findings. Fourth, this RCT used a waitlist control group. An active control, such as supportive group therapy can provide a more rigorous evaluation of intervention effectiveness.

Future research can improve mindfulness trainings by evaluating the effect of dose, including the number of sessions attended as well as the amount of home practice. Moreover, given its usefulness for the evaluation of mindfulness interventions as demonstrated in current and past studies (Moore et al., 2016), consideration of strategies to increase participant adherence to EMA procedures would improve future research. Finally, examinations of person-level moderators of intervention effectiveness, including baseline symptoms and prior experience with mindfulness training in high schools, can help inform secondary prevention efforts.

The current RCT shows compelling evidence that mindfulness training can be an effective prevention strategy for use with first-year college students. Using EMAs, we found that the mindfulness training affects momentary responses to family stress perceived in daily life. The EMA approach to evaluating emotion regulation processes in daily life complement existing evaluation strategies, by enabling clinical and prevention scientists to examine

intervention effects in the real world with the greatest level of specificity and external validity.

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References

Acharya L, Jin L, & Collins W (2018). College life is stressful today–Emerging stressors and depressive symptoms in college students. Journal of American College Health, 66(7), 655–664. [PubMed: 29565759]

Almeida DM, Wethington E, & Chandler AL (1999). Daily transmission of tensions between marital dyads and parent-child dyads. Journal of Marriage and the Family, 61(1), 49–61.

Almeida DM, Wethington E, & Kessler RC (2002). The daily inventory of stressful events: An interview-based approach for measuring daily stressors. Assessment, 9(1), 41–55. [PubMed: 11911234]

Arria AM, Caldeira KM, O'Grady KE, Vincent KB, Fitzelle DB, Johnson EP, & Wish ED (2008). Drug exposure opportunities and use patterns among college students: Results of a longitudinal prospective cohort study. Substance Abuse, 29(4), 19–38.

American College Health Association (2014). American College Health Association-National College Health Assessment II: Reference Group. Executive Summary Spring 2014 Hanover, MD: American College Health Association.

Auerbach RP, Mortier P, Bruffaerts R, Alonso J, Benjet C, Cuijpers P, Demyttenaere K, Ebert DD, Green JG, Hasking P, Murray E, Nock MK, Pinder-Amaker S, Sampson NA, Stein DJ, Vilagut G, Zaslavsky AM, Kessler RC, & WHO WMH-ICS Collaborators (2018). WHO World Mental Health Surveys International College Student Project: Prevalence and distribution of mental disorders. Journal of Abnormal Psychology, 127(7), 623–638. [PubMed: 30211576]

Baete Kenyon D, & Silverberg Koerner S (2009). Examining emerging-adults' and parents' expectations about autonomy during the transition to college. Journal of Adolescent Research, 24(3), 293–320.

Bakosh LS, Snow RM, Tobias JM, Houlihan JL, & Barbosa-Leiker C (2016). Maximizing mindful learning: Mindful awareness intervention improves elementary school students' quarterly grades. Mindfulness, 7(1), 59–67.

Baumeister RF, & Heatherton TF (1996). Self-regulation failure: An overview. Psychological Inquiry, 7(1), 1–15.

Bennett K, & Dorjee D (2016). The impact of a mindfulness-based stress reduction course (MBSR) on well-being and academic attainment of sixth-form students. Mindfulness, 7(1), 105–114.

Bland HW, Melton BF, Welle P, & Bigham L (2012). Stress tolerance: New challenges for millennial college students. College Student Journal, 46(2), 362–376.

Breedvelt J, Amanvermez Y, Harrer M, Karyotaki E, Gilbody S, Bockting CL, Cujipers P, & Ebert DD (2019). The effects of meditation, yoga and mindfulness on depression, anxiety and stress in tertiary education students: A meta-analysis. Frontiers in Psychiatry, 10(193), 1–15. [PubMed: 30723425]

Broderick PC (2013). Learning to Breathe: A Mindfulness Curriculum for Adolescents to Cultivate Emotion Regulation, Attention, and Performance: New Harbinger Publications.

Chung GH, Flook L, & Fuligni AJ (2009). Daily family conflict and emotional distress among adolescents from Latin American, Asian, and European backgrounds. Developmental Psychology, 45(5), 1406–1415. [PubMed: 19702401]

Davidson RJ (2016). Mindfulness-based cognitive therapy and the prevention of depressive relapse: measures, mechanisms, and mediators. JAMA Psychiatry, 73(6), 547–548. [PubMed: 27119526]

Davidson RJ, & Kaszniak AW (2015). Conceptual and methodological issues in research on mindfulness and meditation. American Psychologist, 70(7), 581–592.

Davis MC, Zautra AJ, Wolf LD, Tennen H, & Yeung EW (2015). Mindfulness and cognitive–behavioral interventions for chronic pain: Differential effects on daily pain reactivity and stress reactivity. Journal of Consulting and Clinical Psychology, 83(1), 24–35. [PubMed: 25365778]

Dixon HC, & Overall NC (2016). Dispositional mindfulness attenuates the link between daily stress and depressed mood. Journal of Social and Clinical Psychology, 35(3), 255–268.

Dundas I, Thorsheim T, Hjeltnes A, & Binder PE (2016). Mindfulness based stress reduction for academic evaluation anxiety: a naturalistic longitudinal study. Journal of College Student Psychotherapy, 30(2), 114–131. [PubMed: 27227169]

Dvořáková K, Greenberg MT, & Roeser RW (2019). On the role of mindfulness and compassion skills in students' coping, well- being, and development across the transition to college: A conceptual analysis. Stress and Health, 35(2), 146–156. [PubMed: 30516320]

Dvořáková K, Kishida M, Li J, Elavsky S, Broderick PC, Agrusti MR, & Greenberg MT (2017). Promoting healthy transition to college through mindfulness training with first-year college students: Pilot randomized controlled trial. Journal of American College Health, 65(4), 259–267. [PubMed: 28076182]

Finkelstein-Fox L, Park CL, & Riley KE (2019). Mindfulness' effects on stress, coping, and mood: A daily diary goodness-of-fit study. Emotion, 19(6), 1002–1013. [PubMed: 30138006]

Fledderus M, Bohlmeijer ET, Smit F, & Westerhof GJ (2010). Mental health promotion as a new goal in public mental health care: A randomized controlled trial of an intervention enhancing psychological flexibility. American Journal of Public Health, 100(12), 2372–2372. [PubMed: 20966360]

Franco C, Mañas I, Cangas AJ, Gallego J (2010) The Applications of Mindfulness with Students of Secondary School: Results on the Academic Performance, Self-concept and Anxiety In Lytras MD, Ordonez De Pablos P, Ziderman A, Roulstone A, Maurer H, Imber JB (Eds) Knowledge Management, Information Systems, E-Learning, and Sustainability Research. World Summit on Knowledge Society 2010. Communications in Computer and Information Science (Vol. 111, pp. 83–97). Springer.

Friese M, Messner C, & Schaffner Y (2012). Mindfulness meditation counteracts self-control depletion. Consciousness and Cognition, 21(2), 1016–1022. [PubMed: 22309814]

Geschwind N, Peeters F, Drukker M, van Os J, & Wichers M (2011). Mindfulness training increases momentary positive emotions and reward experience in adults vulnerable to depression: a randomized controlled trial. Journal of Consulting and Clinical Psychology, 79(5), 618–628. [PubMed: 21767001]

Greco LA, Lambert W, & Baer RA (2008). Psychological inflexibility in childhood and adolescence: development and evaluation of the Avoidance and Fusion Questionnaire for Youth. Psychological Assessment, 20(2), 93–102. [PubMed: 18557686]

Gu J, Strauss C, Bond R, & Cavanagh K (2015). How do mindfulness-based cognitive therapy and mindfulness-based stress reduction improve mental health and wellbeing? A systematic review and meta-analysis of mediation studies. Clinical Psychology Review, 37, 1–12. [PubMed: 25689576]

Halladay JE, Dawdy JL, McNamara IF, Chen AJ, Vitoroulis I, McInnes N, & Munn C (2019). Mindfulness for the Mental Health and Well-Being of Post-Secondary Students: A Systematic Review and Meta-Analysis. Mindfulness, 10(3), 397–414.

Heron KE, Everhart RS, McHale SM, & Smyth JM (2017). Using mobile-technology-based ecological momentary assessment (EMA) methods with youth: A systematic review and recommendations. Journal of Pediatric Psychology, 42(10), 1087–1107. [PubMed: 28475765]

Hoeppner BB, Barnett NP, Jackson KM, Colby SM, Kahler CW, Monti PM, Read J, Tevyaw T, Wood M, Corriveau D, & Fingeret A (2012). Daily college student drinking patterns across the first year of college. Journal of Studies on Alcohol and Drugs, 73(4), 613–624. [PubMed: 22630800]

Hofer B (2008). The electronic tether: Parental regulation, self-regulation, and the role of technology in college transitions. Journal of The First-Year Experience & Students in Transition, 20(2), 9–24.

Johnson VK, Gans SE, Kerr S, & LaValle W (2010). Managing the transition to college: Family functioning, emotion coping, and adjustment in emerging adulthood. Journal of College Student Development, 51(6), 607–621.

Kabat- Zinn J (2003). Mindfulness- based interventions in context: past, present, and future. Clinical Psychology: Science and Practice, 10(2), 144–156.

Kashdan TB, & Rottenberg J (2010). Psychological flexibility as a fundamental aspect of health. Clinical Psychology Review, 30(7), 865–878. [PubMed: 21151705]

Keng SL, & Tong EM (2016). Riding the tide of emotions with mindfulness: Mindfulness, affect dynamics, and the mediating role of coping. Emotion, 16(5), 706–7018. [PubMed: 27064290]

Kenney SR, Paves AP, Grimaldi EM, & LaBrie JW (2014). Sleep quality and alcohol risk in college students: examining the moderating effects of drinking motives. Journal of American College Health, 62(5), 301–308. [PubMed: 24588270]

Kroenke K, Strine TW, Spitzer RL, Williams JB, Berry JT, & Mokdad AH (2009). The PHQ-8 as a measure of current depression in the general population. Journal of Affective Disorders, 114(1–3), 163–173. [PubMed: 18752852]

Larose S, Duchesne S, Litalien D, Denault A-S, & Boivin M (2019). Adjustment Trajectories During the College Transition: Types, Personal and Family Antecedents, and Academic Outcomes. Research in Higher Education, 60(5), 684–710.

Lekes N, Houlfort N, Milyavskaya M, Hope NH, & Koestner R (2016). The role of intrinsic values for self-growth and community contribution at different life stages: Differentially predicting the vitality of university students and teachers over one year. Personality and Individual Differences, 98, 48–52.

López-González L, Amutio A, Oriol X, & Bisquerra R (2016). Habits related to relaxation and mindfulness of high school students: Influence on classroom climate and academic performance. Revista de Psicodidáctica, 21(1), 121–138.

Mahfouz J, Levitan J, Schussler D, Broderick T, Dvořáková K, Argusti M, & Greenberg M (2018). Ensuring college student success through mindfulness-based classes: Just breathe. College Student Affairs Journal, 36(1), 1–16.

Mattanah JF, Lopez FG, & Govern JM (2011). The contributions of parental attachment bonds to college student development and adjustment: A meta-analytic review. Journal of Counseling Psychology, 58(4), 565–596. [PubMed: 21823789]

Mitchell JT, McIntyre EM, English JS, Dennis MF, Beckham JC, & Kollins SH (2017). A Pilot Trial of Mindfulness Meditation Training for ADHD in Adulthood: Impact on Core Symptoms, Executive Functioning, and Emotion Dysregulation. Journal of Attention Disorders, 21(13), 1105–1120. [PubMed: 24305060]

Misra R, & McKean M (2000). College students' academic stress and its relation to their anxiety, time management, and leisure satisfaction. American Journal of Health Studies, 16(1), 41–51.

Moore RC, Depp CA, Wetherell JL, & Lenze EJ (2016). Ecological momentary assessment versus standard assessment instruments for measuring mindfulness, depressed mood, and anxiety among older adults. Journal of Psychiatric Research, 75, 116–123. [PubMed: 26851494]

Nahum-Shani I, Smith SN, Spring BJ, Collins LM, Witkiewitz K, Tewari A, & Murphy SA (2017). Just-in-time adaptive interventions (JITAIs) in mobile health: key components and design principles for ongoing health behavior support. Annals of Behavioral Medicine, 52(6), 446–462.

Oken B, Miller M, Goodrich E, & Wahbeh H (2014). Effects of mindfulness meditation on self-rated stress-related measures: improvements in neuroticism and ecological momentary assessment of stress. The Journal of Alternative and Complementary Medicine, 20(5), A64–A64

Robins CJ, Keng SL, Ekblad AG, & Brantley JG (2012). Effects of mindfulness-based stress reduction on emotional experience and expression: A randomized controlled trial. Journal of Clinical Psychology, 68(1), 117–131. [PubMed: 22144347]

Roemer L, Williston SK, & Rollins LG (2015). Mindfulness and emotion regulation. Current Opinion in Psychology, 3, 52–57.

Ruscio AC, Muench C, Brede E, & Waters AJ (2016). Effect of Brief Mindfulness Practice on Self-Reported Affect, Craving, and Smoking: A Pilot Randomized Controlled Trial Using Ecological Momentary Assessment. Nicotine & Tobacco Research, 18(1), 64–73. [PubMed: 25863520]

Schneider S, & Stone AA (2016). Ambulatory and diary methods can facilitate the measurement of patient-reported outcomes. Quality of Life Research, 25(3), 497–506. [PubMed: 26101141]

Sliwinski MJ (2008). Measurement burst designs for social health research. Social and Personality Psychology Compass, 2(1), 245–261.

Spears CA, Li L, Wu C, Vinci C, Heppner WL, Hoover DS, Lam C & Wetter DW (2019). Mechanisms linking mindfulness and early smoking abstinence: An ecological momentary assessment study. Psychology of Addictive Behaviors, 33(3), 197–207. [PubMed: 30829517]

Spitzer RL, Kroenke K, Williams JB, & Löwe B (2006). A brief measure for assessing generalized anxiety disorder: the GAD-7. Archives of Internal Medicine, 166(10), 1092–1097. [PubMed: 16717171]

Towbes LC, & Cohen LH (1996). Chronic stress in the lives of college students: Scale development and prospective prediction of distress. Journal of Youth and Adolescence, 25(2), 199–217.

Trapnell PD, & Campbell JD (1999). Private self-consciousness and the five-factor model of personality: distinguishing rumination from reflection. Journal of Personality and Social Psychology, 76(2), 284–304. [PubMed: 10074710]

Van Reen E, Roane BM, Barker DH, McGeary JE, Borsari B, & Carskadon MA (2016). Current alcohol use is associated with sleep patterns in first-year college students. Sleep, 39(6), 1321–1326. [PubMed: 27070138]

Wagner DD, & Heatherton TF (2012). Self-regulatory depletion increases emotional reactivity in the amygdala. Social Cognitive and Affective Neuroscience, 8(4), 410–417. [PubMed: 22842815]

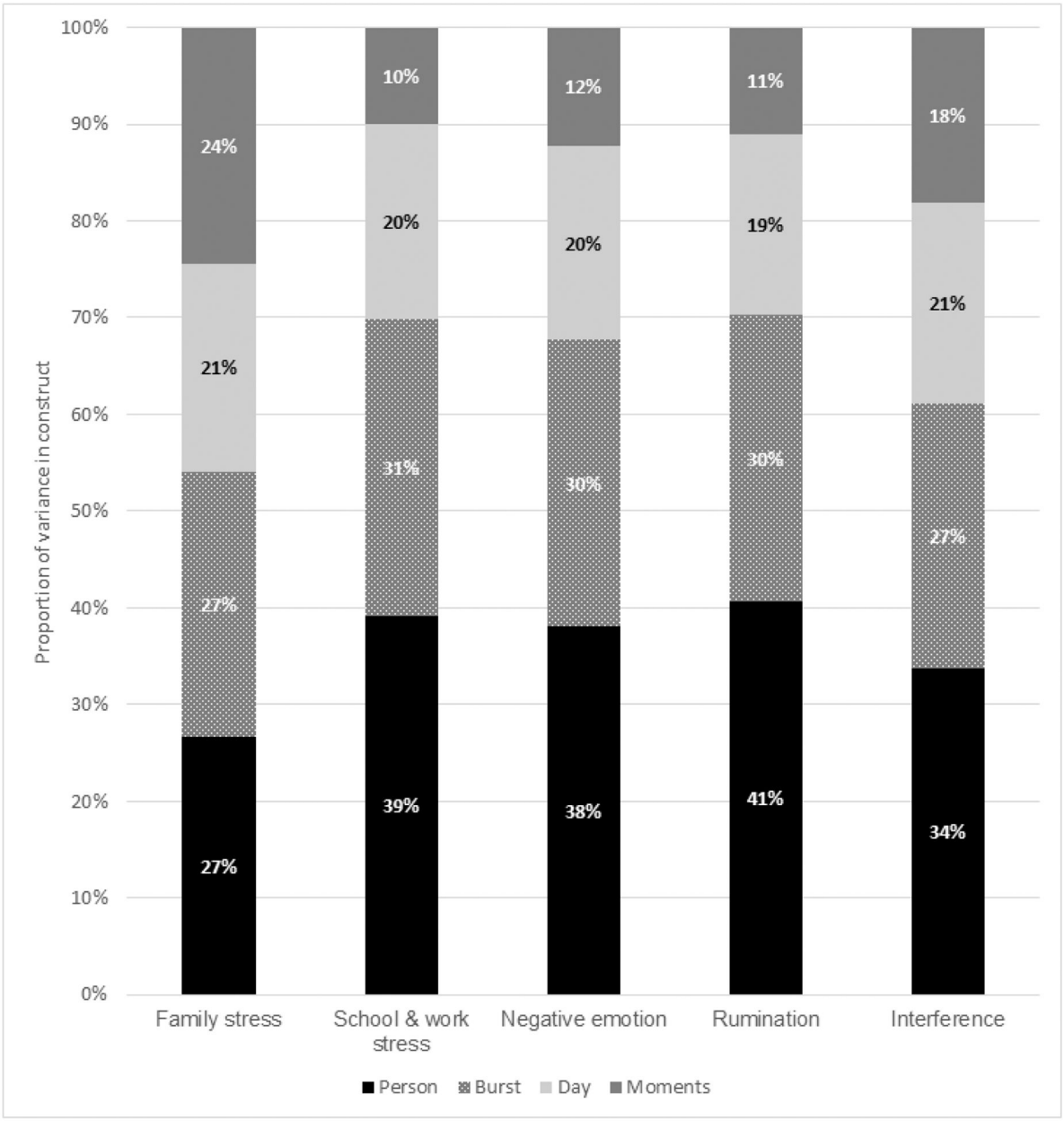

Figure 1.
Proportion of variance attributable to differences between individuals, bursts, days and moments

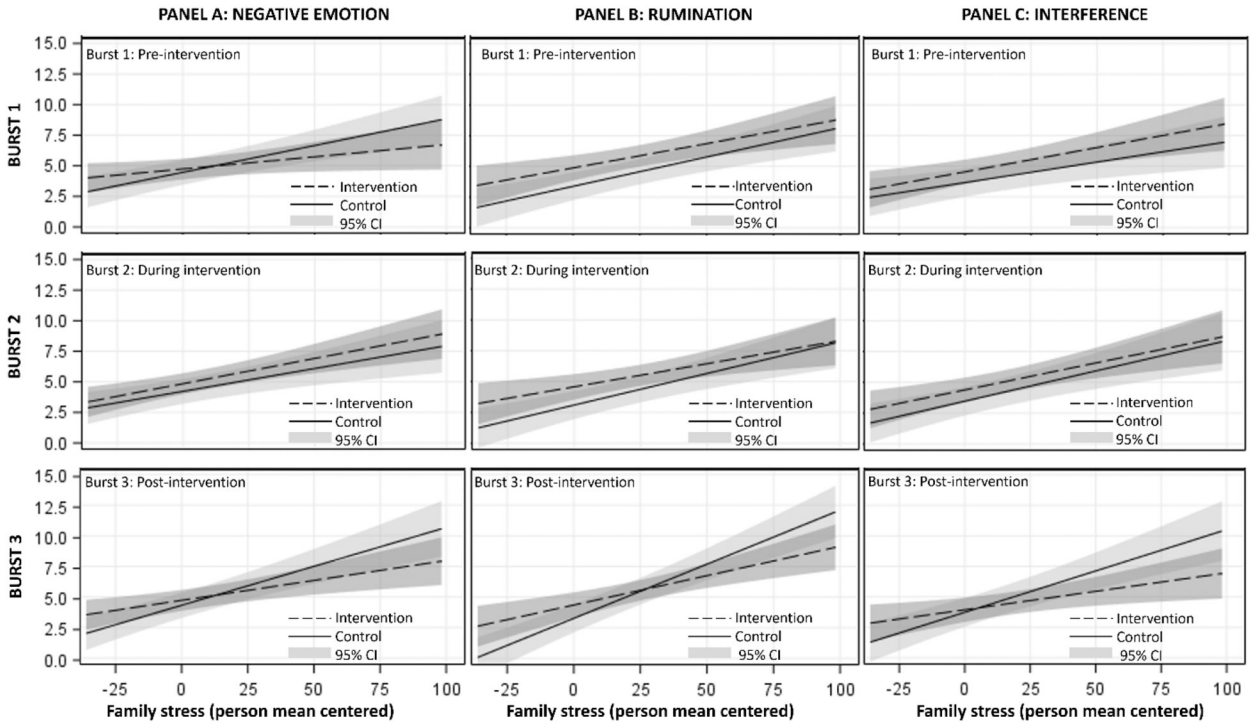

Figure 2.

Moment-level associations between family stress and negative emotion, rumination and interference, by burst for the average participant in the intervention and control conditions Panel A displays associations between family stress and negative emotion at Bursts 1, 2 and 3. Panel B displays associations between family stress and rumination at Bursts 1, 2 and 3. Panel C displays associations between family stress and interference at Bursts 1, 2 and 3. Note: Negative emotion, rumination and interference were square root transformed to reduce the positive skew. Covariates included mean levels of family stress (grand mean centered), weekend status (0=weekday), day in the study (0=day 1), history of therapy or counseling (effect coded −1=nom 1=yes), and gender coded (−1=female, 1=male).

Table 1

Descriptive statistics of stress, negative emotion, rumination and interference by intervention group and burst

		Descriptive statistics										Intervention and burst effects		
Variable	**Burst**	**Total**				**Control**			**Intervention**					
		N	**M**	**SD**	**Range**	**N**	**M**	**SD**	**N**	**M**	**SD**		**F statistic**	**p**
Stress														
Family conflict														
	1	1373	6.41	14.60	0–100	777	6.38	14.51	596	6.46	14.74	Intervention	F(1, 48)=2.23	0.142
	2	1115	8.06	16.96	0–100	610	6.12	15.55	505	10.41	18.26	Burst	F(2, 91)=0.56	0.575
	3	953	8.61	17.03	0–100	471	7.07	14.14	482	10.11	19.33	Intv × Burst	F(2, 3383)= 1.05	0.349
Occupational problems														
	1	1371	27.93	31.04	0–100	776	24.48	29.22	595	32.44	32.74	Intervention	F(1, 48)=1.90	0.175
	2	1114	29.02	32.91	0–100	610	23.46	32.06	504	35.74	32.71	Burst	F(2, 91)= 1.05	0.353
	3	952	24.18	30.29	0–100	470	19.33	27.18	482	28.92	32.38	Intv × Burst	F(2, 3379)=1.02	0.359
Emotion regulation														
Negative Emotion														
	1	1381	20.54	21.01	0–100	782	18.00	19.47	599	23.85	22.45	Intervention	F(1, 48)=1.79	0.187
	2	1122	21.01	21.93	0–100	613	17.78	21.80	509	24.91	21.47	Burst	F(2, 91)=0.65	0.526
	3	956	20.59	21.12	0–100	473	17.09	19.00	483	24.02	22.49	Intv × Burst	F(2, 3401)=0.83	0.434
Rumination														
	1	1374	27.12	27.25	0–100	778	22.70	25.21	596	32.89	28.72	Intervention	F(1, 48)=3.28	0.076
	2	1116	25.37	25.52	0–100	611	20.95	24.23	505	30.71	26.03	Burst	F(2, 91)=0.76	0.469
	3	953	25.27	25.51	0–100	471	21.51	23.88	482	28.94	26.53	Intv × Burst	F(2, 3385)=0.75	0.474
Interference														
	1	1376	24.26	27.36	0–100	779	21.54	25.52	597	27.80	29.24	Intervention	F(1, 48)=1.84	0.181
	2	1119	23.75	26.62	0–100	612	20.19	25.36	507	28.04	27.49	Burst	F(2, 91)=0.85	0.431
	3	954	22.91	26.37	0–100	473	21.55	25.34	481	24.24	27.30	Intv × Burst	F(2, 3391)= 1.76	0.172

Note: Intervention and burst effects were tested in four-level regression models that included random intercepts at the level of the days, bursts and persons and first-order autoregressive covariance structure for the residuals. Models controlled for weekend status, day in burst, history of therapy and gender. Outcomes were square-root transformed in the regression models to reduce positive skew.

Table 2

Results of four-level regressions testing intervention effect on momentary emotion regulation responses to family stress

	Negative Emotion			Rumination			Interference		
Fixed effects	**B**	**SE**	**95% CI**	**B**	**SE**	**95% CI**	**B**	**SE**	**95% CI**
Intercept	4.47***	0.52	3.43, 5.51	3.38***	0.57	2.22, 4.53	3.67***	0.59	2.49, 4.85
Stress	0.04***	0.01	0.03, 0.06	0.05***	0.01	0.03, 0.07	0.03**	0.01	0.01, 0.05
Intervention (Intv)	0.27	0.54	−0.81, 1.36	1.50*	0.66	0.17, 2.83	0.87	0.63	−0.40, 2.15
Burst 2	−0.24	0.22	−0.68, 0.21	−0.28	0.24	−0.76, 0.20	−0.20	0.25	−0.69, 0.30
Burst 3	−0.14	0.24	−0.62, 0.34	−0.11	0.26	−0.62, 0.41	0.07	0.26	−0.46, 0.59
Stress × Intv	−0.02	0.01	−0.05, 0.00	−0.01	0.02	−0.04, 0.02	0.01	0.02	−0.02, 0.04
Stress × Burst 2	−0.01	0.01	−0.03, 0.01	0.00	0.01	−0.01, 0.02	0.02	0.01	−0.01, 0.04
Stress × Burst 3	0.02	0.01	−0.00, 0.04	0.04***	0.01	0.02, 0.06	0.03*	0.01	0.01, 0.06
Intv × Burst 2	0.35	0.35	−0.33, 1.03	−0.02	0.37	−0.75, 0.71	0.04	0.38	−0.71, 0.79
Intv × Burst 3	0.13	0.36	−0.57, 0.83	−0.41	0.38	−1.16, 0.34	−0.67	0.39	−1.44, 0.10
Stress × Intv × Burst 2	0.03*	0.01	0.00, 0.06	−0.01	0.01	−0.03, 0.02	−0.01	0.02	−0.04, 0.02
Stress × Intv × Burst 3	−0.01	0.02	−0.04, 0.02	−0.03*	0.01	−0.06, −0.00	−0.04*	0.02	−0.08, −0.01
Mean Stress	0.11***	0.03	0.06, 0.16	0.05	0.02	−0.00, 0.10	0.08**	0.03	0.03, 0.14
Weekend	−0.17	0.09	−0.35, 0.02	−0.04	0.09	−0.21, 0.13	0.10	0.11	−0.10, 0.31
Day in study	−0.04*	0.02	−0.07, −0.00	0.01	0.02	−0.02, 0.04	−0.02	0.02	−0.05, 0.02
History of therapy	0.85*	0.38	0.10, 1.61	−0.11	0.38	−0.87, 0.65	0.31	0.41	−0.52, 1.14
Gender	−0.09	0.25	−0.58, 0.4	−0.55*	0.25	−1.04, −0.05	−0.39	0.27	−0.94, 0.15
Random effects	**Var**	**SE**	**95% CI**	**Var**	**SE**	**95% CI**	**Var**	**SE**	**95% CI**
Person									
Intercept	2.33***	0.54	1.55, 3.89	4.03***	0.93	2.69, 6.70	3.43***	0.78	2.30, 5.66
Stress	0.001**	0.000	0.000, 0.002	0.002**	0.001	0.001, 0.004	0.001**	0.000	0.001, 0.003
Covariance	−0.01	0.01	−0.03, 0.01	−0.07***	0.02	−0.10, −0.03	−0.04*	0.02	−0.07, −0.01
Burst									
Intercept	0.50***	0.11	0.34, 0.82	0.62***	0.12	0.43, 0.96	0.59***	0.13	0.40, 0.96
Day									

Intercept	0.77***	0.09	0.63, 0.97	0.60***	0.09	0.45, 0.84	0.80***	0.12	0.60, 1.11
Stress	0.001***	0.000	0.000, 0.001	0.001***	0.000	0.001, 0.002	0.001***	0.000	0.001, 0.002
Covariance	−0.02***	0.00	−0.02, −0.01	−0.03***	0.00	−0.04, −0.03	−0.03***	0.01	−0.04, −0.02
Moment									
AR(1)	−0.03	0.03	−0.10, 0.03	0.04	0.04	−0.03, 0.11	0.02	0.04	−0.05, 0.09
Residual	2.26***	0.08	2.11, 2.41	2.63***	0.10	2.45, 2.82	3.41***	0.12	3.18, 3.67

* p < .05,

** p < .01,

*** p <.001;

Note: Burst 1=pre intervention (reference group), Burst 2=during intervention, Burst 3=post intervention; past 6-month therapy effect coded (−1=no, 1=yes); gender effect coded (−1=female, 1=male); intervention (0=control, 1=mindfulness). Models included random intercepts at the level of the days, bursts and persons, random slope effects of stress at the day and person levels, as well a first-order autoregressive covariance structure for the residuals. Emotion regulation variables were square-root transformed in the regression models to reduce positive skew.

Table 3

Post-hoc analysis of the associations between family stress response and negative emotion, rumination and interference, by intervention condition and burst

	Control				Intervention				Δ *Intervention - Control*			
	B	**SE**	**95% CI**	**p**	**B**	**SE**	**95% CI**	**p**	**Δ B**	**SE**	**95% CI**	**p**
Negative emotion												
Burst 1	0.04	0.01	0.03, 0.06	<.001	0.02	0.01	0.00, 0.04	.049	−0.02	0.01	−0.05, 0.00	.084
Burst 2	0.04	0.01	0.02, 0.06	<.001	0.04	0.01	0.02, 0.06	<.001	0.00	0.01	−0.02, 0.03	.789
Burst 3	0.06	0.01	0.04, 0.09	<.001	0.03	0.01	0.01, 0.05	.001	−0.03	0.01	−0.06, −0.00	.037
Δ Burst 2 - Burst1	−0.01	0.01	−0.03, 0.01	.514	0.02	0.01	0.00, 0.04	.035	--	--	--	--
Δ Burst 3 - Burst2	0.03	0.01	0.00, 0.05	.030	−0.01	0.01	−0.03, 0.01	.394	--	--	--	--
Δ Burst 3 - Burst1	0.02	0.01	−0.00, 0.04	.096	0.01	0.01	−0.01, 0.03	.231	--	--	--	--
Rumination												
Burst 1	0.05	0.01	0.03, 0.07	<.001	0.04	0.01	0.02, 0.06	.001	−0.01	0.02	−0.04, 0.02	.601
Burst 2	0.05	0.01	0.03, 0.07	<.001	0.04	0.01	0.01, 0.06	.002	−0.01	0.02	−0.05, 0.02	.400
Burst 3	0.09	0.01	0.07, 0.11	<.001	0.05	0.01	0.02, 0.07	<.001	−0.04	0.02	−0.07, −0.01	.015
Δ Burst 2 - Burst1	0.00	0.01	−0.01, 0.02	.703	−0.00	0.01	−0.02, 0.02	.827	--	--	--	--
Δ Burst 3 - Burst2	0.04	0.01	0.01, 0.06	.001	0.01	0.01	−0.01, 0.03	.289	--	--	--	--
Δ Burst 3 - Burst1	0.04	0.01	0.02, 0.06	<.001	0.01	0.01	−0.01, 0.03	.409	--	--	--	--
Interference												
Burst 1	0.03	0.01	0.01, 0.05	.002	0.04	0.01	0.02, 0.06	<.001	0.01	0.02	−0.02, 0.04	.699
Burst 2	0.05	0.01	0.03, 0.07	<.001	0.04	0.01	0.02, 0.07	<.001	−0.01	0.02	−0.04, 0.03	.748
Burst 3	0.07	0.01	0.04, 0.09	<.001	0.03	0.01	0.01, 0.05	.009	−0.04	0.02	−0.07, −0.00	.027
Δ Burst 2 - Burst1	0.02	0.01	−0.01, 0.04	.171	0.00	0.01	−0.02, 0.03	.721	--	--	--	--
Δ Burst 3 - Burst2	0.02	0.01	−0.01, 0.05	.174	−0.01	0.01	−0.04, 0.01	.253	--	--	--	--
Δ Burst 3 - Burst1	0.03	0.01	0.01, 0.06	.010	−0.01	0.01	−0.03, 0.01	.440	--	--	--	--

Δ indicates difference in slopes; Burst 1=pre intervention (reference group), Burst 2=during intervention, Burst 3=post intervention