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ORIGINAL PAPER

Training in Mindfulness or Loving-kindness Meditation Is Associated with Lower Variability in Social Connectedness Across Time

Brian P. Don[1] · **Patty Van Cappellen**[2] · **Barbara L. Fredrickson**[3]

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Abstract

Objectives Research demonstrates that meditation interventions tend to positively influence social well-being. Yet, prior research has exclusively examined meditation in relation to average levels of social outcomes (e.g., social connectedness), despite other work demonstrating variability or fluctuations in social functioning play a distinct role in contributing to well-being. This study examined the hypothesis that training in mindfulness meditation and loving-kindness meditation would predict lower *variability* in social connectedness, even accounting for their positive influence on average levels of social connectedness. Moreover, this study also examined the hypothesis that lower variability in positive and negative emotions would mediate the link between training in meditation and reduced variability in social connectedness.

Methods These hypotheses were tested using a randomized study of 224 mid-life adults. Participants received training in either mindfulness or loving-kindness meditation for 6 weeks. They reported their daily social connectedness and emotions for 2 weeks prior to the training, 6 weeks during the training, and 3 weeks after the training.

Results Consistent with hypotheses, results demonstrated that participants in both meditation groups reported lower variability in social connectedness across the course of the intervention, even accounting for average levels of connectedness. Moreover, lower positive and negative affective variability partially mediated the association between time (training in meditation) and reduced variability in social connectedness.

Conclusions These results suggest that (a) meditation may help to smooth social ups and downs across time and that (b) it may do so via its association with reduced affective variability.

Keywords Mindfulness meditation · Loving-kindness meditation · Social connectedness · Affective variability

Research demonstrates that meditation contributes to social well-being. For instance, mindfulness meditation — which involves training individuals to focus their attention on present-focused thoughts, feelings, and experiences in an accepting way — contributes to benefits in the social domain (Creswell et al., 2012; Kappen et al., 2019; Karremans et al., 2020; Lindsay et al., 2019). As one example, in two randomized trials using ambulatory assessment methods in daily life, participants who completed training in mindfulness meditation reported reduced loneliness and increased self-reported frequency of interacting with other people as compared to participants in an active control group (Lindsay et al., 2019).

In addition to mindfulness meditation, loving-kindness meditation involves an overt social focus during the actual practice of the meditation itself. Indeed, during loving-kindness meditation, participants are instructed to direct warm, kind-hearted thoughts and well-wishes towards a series of other individuals, which theoretically cultivates the individual's innate capacity for compassion and kindness (Salzberg, 2002). As such, it is perhaps not surprising that prior empirical work has demonstrated that loving-kindness meditation beneficially contributes to greater social connectedness (Hutcherson et al., 2008), greater perceptions of social support (Fredrickson et al., 2008), and lower social avoidance motivation (Don et al., 2021a; Don et al., 2021b). While mindfulness and loving-kindness meditation share some

✉ Brian P. Don
brian.don@ucsf.edu

[1] Department of Psychiatry and Behavioral Sciences, University of California, San Francisco, San Francisco, USA

[2] Social Science Research Institute, Duke University, Durham, USA

[3] Department of Psychology and Neuroscience, University of North Carolina at Chapel Hill, Chapel Hill, USA

similarities (e.g., they are both quiet, contemplative practices with an intentional focus point, such as the breath), one of the critical differences between the two is that mindfulness involves open and receptive attention towards all experiences occurring in the present moment, whereas loving-kindness meditation involves overtly cultivating compassion and goodwill, even if that was not the individual's natural experience in the present moment.

Despite this extant body of literature demonstrating that both mindfulness and loving-kindness meditation contribute to enhanced social well-being, all of the prior research has examined how meditation practice contributes to enhanced social well-being in terms of average levels of these outcomes (e.g., Lindsay et al., 2019). While it is, of course, important to examine how meditation interventions influence average levels of key social outcomes, by focusing exclusively on average levels of relational outcomes, prior research has omitted the following question: how do meditation interventions contribute to variability in social outcomes?

In daily life, it is commonplace for people to report fluctuations in feelings of social connectedness, relationship satisfaction, or social support (Arriaga, 2001; Campbell et al., 2010; Eastwick et al., 2019; Girme et al., 2018). Importantly, emerging research suggests these fluctuations in relationship experiences have significant implications for relational well-being, even independently of average levels of these outcome, with most research suggesting that consistency in relational experiences tends to be beneficial, as compared to greater levels of relational variability (Arriaga, 2001; Arriaga, et al., 2006; Campbell et al., 2010; Girme et al., 2018). Notably, relational fluctuations may not always be associated with maladaptive outcomes, as there may be certain contexts or relational behaviors for which fluctuations are associated with beneficial outcomes (e.g., Overall, 2020). Generally speaking, however, the extant literature suggests that greater variability in social factors such as attachment security, social connectedness, or relationship satisfaction tends to be associated with maladaptive outcomes.

Taken together, despite research showing that (a) variability in social connection plays a detrimental role for well-being and (b) meditation interventions enhance average levels of social well-being, no research has considered the possibility that meditation interventions may also beneficially influence variability in social connectedness. Numerous theoretical reasons exist to suggest that both mindfulness and loving-kindness meditation may influence variability in social connectedness, in addition to average levels. For instance, an extensive body of literature has examined how the cultivation of mindfulness via mediation may modulate the way people experience social threats (Brown et al., 2012; Clear et al., 2021; Creswell et al., 2014; Molet et al., 2013). For most people, being the subject of social evaluation, social stress, or social exclusion hurts, as these types of social experiences predict hurt feelings, lower belonging, and psychophysiological reactivity (Williams et al., 2000; Zadro et al., 2004). Yet, research suggests that mindfulness — including mindfulness meditation — tends to modulate people's responses to social threats, and render them less psychologically difficult (Brown et al., 2012; Clear et al., 2021; Cresswell et al., 2014; Molet et al., 2013). In this way, whereas someone untrained in mindfulness meditation may experience social threats that occur in everyday life as particularly challenging (and therefore experience strong decrements in their sense of connectedness), people trained in mindfulness meditation may be more resilient to social threats, and therefore experience lower variability in social connectedness across the course of everyday life.

Loving-kindness meditation, similarly, represents a fundamental reorientation towards oneself and other people that is likely to reduce variability in one's sense of social connectedness. Loving-kindness meditation has been shown to enhance implicit (positive) attitudes towards other people (Hutcherson et al., 2008), the feeling that others are available for support (Fredrickson et al., 2008), and self-compassion (e.g., Boellinghaus et al., 2014). As such, engaging in a regular practice that cultivates a sense of compassion and warmth towards others is likely not only to result in greater average levels of social connectedness, but also more consistency in feelings of social connectedness.

As outlined above, good reason exists to suggest that training in mindfulness mediation or loving-kindness meditation may influence variability in social connectedness across the course of time. But, what are the precise mechanisms by which meditation training may influence variability in social connectedness? Although there are many possible mechanisms, one plausible mediator is affective variability. Affective variability refers to the extent to which people experience fluctuations in their emotions across the course of a particular period of time (Eid & Diener, 1999). Prior research demonstrates that lower affective variability tends to be beneficially associated with a host of important outcomes, including reduced depressive symptoms (Wichers et al., 2010), symptoms of other psychopathology (Russell et al., 2007), and higher self-esteem (Kuppens et al., 2007).

Affective variability is a likely mediator between meditation training and variability in social connectedness for two reasons. First, extensive research demonstrates that mindfulness meditation tends to beneficially influence affect, including increasing positive emotions and decreasing negative emotions, both in daily life and across time (see Eberth & Sedlmeier, 2012 for a review). While research on loving-kindness meditation suggests this practice most consistently influences positive emotions (Fredrickson et al., 2017; Zeng

et al., 2015), some studies demonstrate it is also associated with reductions in negative emotions as well (see Shonin et al., 2015 for a review). Although almost all of the prior research has focused on the influence of mindfulness meditation and loving-kindness meditation on average levels of affect, two studies have recently demonstrated that mindfulness meditation contributes to reductions in negative affective variability (Colgan et al., 2019; Keng et al., 2021). Regarding loving-kindness meditation, no prior research has directly investigated its effects on affective variability. However, loving-kindness meditation has been shown to enhance (a) average levels of affect and (b) the emotional regulation skills (e.g., self-compassion; Shahar et al., 2015; Germer & Neff, 2013) needed to reduce affective variability.

Second, affective experiences likely play an explanatory role in understanding why mindfulness and loving-kindness meditation contribute to variability in social connectedness because affect plays a critical role in promoting social connectedness. For instance, extensive research demonstrates that positive emotions create a broadened focus, which in turn promotes greater self-other overlap (Waugh & Fredrickson, 2006), enhanced social support during challenging times (Don, Algoe, et al., 2021; Don et al., 2021b), and the general building of social bonds (Fredrickson et al., 2008). Negative emotions, conversely, tend to create a narrowed attention, self-focus, and rigid self-absorption that can hamper the building of social bonds (e.g., Farmer & Kashdan, 2012; Kashdan & Roberts, 2007). Although prior research has primarily examined how mean levels of affective experiences contribute to social connectedness, there is reason to suspect reductions in affective variability may mediate the association between meditation training and lower variability in social connectedness. In particular, theory in affective and relationship science suggests that affective variability begets social variability: those people who experience extensive variability in their positive and negative emotions are likely the same people who tend to experience extensive variability in their social relationships. As an example, if an individual experiences a high degree of positive emotion 5 days per week, but little positive emotion 2 days per week, based on the impact of positive emotions on perceived connection (e.g., Fredrickson et al., 2008; Waugh & Fredrickson, 2006), they likely experience enhanced social connectedness on the days of the week in which they experience greater positive emotions. Yet, on the days in which they experience little positive emotion, they are likely less engaged in the building of social bonds, thereby resulting in a high degree of variability in their social connectedness across the course of that week (a similar pattern would likely occur for variability in negative emotions).

The goal of this study was to examine whether training in mindfulness or loving-kindness meditation predicted lower variability in social connectedness across the course of time, and whether concomitant changes in affective variability mediated the association between meditation training and lower variability in social connectedness across time. Hypothesis 1 was that individuals trained in mindfulness or loving-kindness meditation would report reductions in variability in social connectedness across the course of the study. Hypothesis 2 was that reduced variability in negative and positive affective variability would mediate the association between meditation training and lower variability in social connectedness across time. Although no a priori hypotheses were put forth regarding differences between the two groups in terms of social and affective variability, differences between participants trained in mindfulness and loving-kindness meditation were also examined in an exploratory manner.

One prior publication (Fredrickson et al., 2019) has drawn upon these archival data while utilizing social connectedness as an outcome variable. In that publication, the primary purpose was to examine whether there was a dose–response, daily association between informal contemplative moments and positive emotions, negative emotions, and social connectedness. Daily formal meditation was also included as a control variable in that previous publication. The current research is distinct from that prior research because the focus of this research is on (a) variability in social connectedness, positive emotions, and negative emotions (as opposed to average levels) and (b) change in each of these variables across the 11-week study period, as opposed to daily, dose–response analyses. As outlined in the introduction, variability in social connectedness has never been examined in relation to meditation interventions, including in these data.

Methods

Participants

The archival data from the NIH-funded study (R01CA170128) have been used in prior publications (Fredrickson et al., 2017, 2019). Participants were 224 individuals who were drawn from the community surrounding a large university in the Southwest of the USA. Although 231 participants were originally randomized to receive the intervention, only 224 complete the measures needed for the purposes of this research. Participants ranged from 35 to 67 years old, and were eligible if they had no prior meditation experience and no physical disabilities or chronic illnesses, and if they had access to the internet from their home. Participants were 48.62 years old on average ($SD = 8.95$). With respect to gender identity, 59.2% of participants identified as women, and 40.8% of participants identified as men. With respect to race, 77.5% of participants

identified as White, 17.0% of participants identified as Black or African-American, 5.0% of participants identified as Asian, and 0.5% of participants identified as American Indian or Alaska Native. With respect to ethnicity, 3.7% of participants identified as Hispanic or Latino, with all other participants identifying as not Hispanic or Latino.

Procedure

After recruitment, participants first came to a laboratory for an intake session, where they completed a series of assessments not relevant to the present research. Participants were subsequently e-mailed surveys each day across the course of the next 11 weeks, in which they reported their daily feelings of social connection, positive emotions, and negative emotions. The first 2 weeks of the study were used to establish a baseline. Then, across the course of the next 6 weeks (and based on random-assignment), participants attended classes in either mindfulness or loving-kindness meditation. Participants continued reporting their daily connectedness and emotions for 3 weeks after they finished attending meditation classes. These 11 total weeks of daily reports were used to examine change trajectories of weekly variability in social connectedness. Daily reports within each week (up to 7 total reports for each week) were used to calculate within-person standard deviations for each week of data collection. Given the design of this study, and consistent with prior research examining affective variability (e.g., Keng et al., 2021), within-person standard deviations in both social connectedness and affect across the course of a week were used because they provided a large enough time interval for fluctuations to occur, while also meaning that there were enough individual weeks per person (11) such that longitudinal trajectories of change in within-person fluctuations could be examined.

Meditation classes for all participants occurred once per week, in-person, and each class had a maximum enrollment of 16 people. Participants were provided with at-home, guided meditations, and encouraged to engage in at-home practice, 3–5 times per week, and 20 min per day. If participants were unable to attend a class in a particular week, they were instructed to continue with at-home practice, and to attend class the following week. In the mindfulness intervention, participants were taught how to direct their attention to present-moment experiences with an open, accepting awareness. In accordance with the model of mindfulness put forth by Shapiro et al. (2006), the overarching goal of this intervention was to enable participants to meta-cognitively view the ongoing stream of experiences from a less reactive, and more equanimous perspective. The goal of the loving-kindness meditation was to help the practitioner cultivate their innate capacity for kindness and compassion (Salzberg, 2002). While self-generating warm-hearted feelings, participants were directed to repeat a series of kind and compassionate phrases towards a series of targets, including towards themselves and other people. Both interventions were developed in consultation with experts, and were led by teachers with extensive experience. More information on both interventions can be found in prior publications (Fredrickson et al., 2017, 2019).

Measures

Social Connectedness Social connectedness was assessed daily, using the following item: "In the past 24 h, how much did you feel socially integrated or 'on the same page' with others?" Participants responded on a scale from 1 = *not at all* to 7 = *completely*. Within-person standard deviations were calculated using each individual's daily reports of social connectedness across the course of each week of the study (week 1 — 11). Weekly means for social connectedness for each week of the study were also calculated, and used as a covariate in subsequent analyses.

Positive and Negative Emotions The daily version of the modified Differential Emotions Scale (Fredrickson, 2013) was used to assess positive and negative emotions. Each day, participants reported on the extent to which they experienced 10 sets of positive emotions (e.g., "Amused, Fun-Loving, Silly," "Glad, Happy, Joyful") and 10 sets of negative emotions (e.g., "Scared, Fearful, Afraid," "Stressed, Nervous, Overwhelmed") over the past 24 h on a scale from 0 = *not at all* to 4 = *extremely* (positive emotions Chronbach's $\alpha = 0.90$, McDonald's $\omega = 0.93$; negative emotions Chronbach's $\alpha = 0.84$, McDonald's $\omega = 0.87$). As with social connectedness, weekly within-person standard deviations and means were calculated and used in subsequent analyses.

Data Analyses

To examine whether (a) training in mindfulness and loving-kindness meditation predicted reductions in variability in social connectedness and (b) whether these reductions were mediated by reductions in variability in positive and negative emotions, data analysis was conducted in two steps. First, multilevel growth curve analyses were conducted according to the recommendations of Bolger and Laurencaeu (2013), to examine change in participants' weekly variability (within-person standard deviations) in social connectedness from the start of the study (week 1, prior to the intervention) until the end of the study (week 11, after the intervention). As is common practice in growth curve modeling, the linear trajectory of variability in social connectedness was modeled with a random intercept and slope. We also specified a quadratic component for time, to account for the possibility that there may be non-linear patterns of change in variability in social connectedness (e.g., participants may experience

considerable change early in the intervention, which then tapers off later in the intervention, or after the end of the intervention). Condition was included as a moderator of both the linear and quadratic effects of time, to examine whether the pattern of change in fluctuations in social connectedness across time was significantly different for individuals trained in mindfulness meditation or loving-kindness mediation. Consistent with prior research (e.g., Girme et al., 2018; Overall, 2020), weekly mean levels of social connectedness were also included as a covariate, to examine the pattern of change in variability in social connectedness, independent of mean levels of social connectedness. In an ancillary analysis, mean levels of social connectedness were included as a moderator, to test the possibility that change in variability social connectedness across the course of the intervention was dependent on mean levels. For instance, it is possible that people who are low in average levels of social connectedness may be especially likely to experience reductions in variability in social connectedness across the course of time.

After examining the longitudinal pattern of change in fluctuations in social connectedness across the course of the study, multilevel growth curve mediation analyses were conducted using the MLmed macro in SPSS (Hayes & Rockwood, 2020). MLmed uses Monte Carlo simulation to calculate unbiased confidence intervals for indirect effects in the context of multilevel modeling, including in contexts where multiple mediators are specified. We tested two models, and the key tests of interest were the indirect effects of the time (week of the study) → weekly positive or negative affect variability → weekly social connectedness variability. Because prior research suggests that both mindfulness meditation and loving-kindness meditation influence average levels of positive and negative emotions, in each of these models, weekly mean levels of positive or negative emotions were also specified as an alternative mediator, to account for the possibility that the meditation interventions may be influencing variability in social connectedness via average levels of affect, and not via variability in affect. As in the initial growth curve model, we also included average levels of weekly social integration as a covariate. Finally, the MLmed macro also allows for testing moderated mediation, which enabled inclusion of the condition variable (mindfulness or loving-kindness meditation) as a moderator of the indirect effects of interest. This meant we were able to examine whether the indirect effects of time weekly positive or negative affective variability weekly social connectedness variability were moderated by meditation condition, or in other words whether the indirect effects were similar depending on whether participants were trained in mindfulness or loving-kindness meditation.

Power analyses were calculated a priori, for the aims of the original study for which these data were collected. Additionally, we examined the power curve for two-level, multilevel models presented in Bolger and Laurenceau (2013), which suggested that with 224 participants, and 2249 total observations (up to 11 observations per individual), the analyses used in this research would be well-powered to detect medium-sized effects.

Results

Descriptive statistics and bivariate correlations are presented in Table 1. Bivariate correlations, which are presented in Table 2, demonstrated that weekly variability in positive and negative emotions was associated with greater weekly variability in social connectedness. Additionally, meditation condition was not significantly associated with weekly

Table 1 Descriptive statistics for primary study variables

	Social connectedness *M*		Social connectedness within-person *SD*		Negative emotions *M*		Negative emotions within-person *SD*		Positive emotions *M*		Positive emotions within-person *SD*	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Week 1	4.34	1.28	0.83	0.49	0.62	0.42	0.37	0.20	1.86	0.71	0.44	0.22
Week 2	4.29	1.32	0.67	0.46	0.51	0.46	0.25	0.21	1.82	0.77	0.39	0.20
Week 3	4.38	1.29	0.63	0.44	0.53	0.40	0.32	0.18	1.73	0.72	0.44	0.22
Week 4	4.47	1.34	0.55	0.42	0.46	0.43	0.22	0.17	1.77	0.77	0.36	0.21
Week 5	4.44	1.36	0.56	0.40	0.53	0.43	0.33	0.20	1.73	0.71	0.42	0.21
Week 6	4.51	1.35	0.57	0.45	0.44	0.44	0.23	0.22	1.83	0.78	0.34	0.20
Week 7	4.58	1.26	0.56	0.44	0.54	0.43	0.34	0.19	1.77	0.72	0.44	0.22
Week 8	4.63	1.25	0.56	0.44	0.44	0.44	0.21	0.19	1.86	0.77	0.34	0.22
Week 9	4.59	1.25	0.61	0.51	0.52	0.39	0.34	0.22	1.83	0.72	0.43	0.21
Week 10	4.68	1.28	0.53	0.47	0.42	0.42	0.20	0.19	1.95	0.78	0.31	0.21
Week 11	4.69	1.30	0.56	0.46	0.51	0.37	0.35	0.23	1.88	0.72	0.43	0.22

Table 2 Bivariate correlations for primary study variables

	1	2	3	4	5	6	7
1. Weekly social connectedness WP *SD*	-						
2. Weekly social connectedness *M*	−.15**	-					
3. Weekly positive emotions WP *SD*	.34**	.13**	-				
4. Weekly positive emotions *M*	−.14**	.61**	.14**	-			
5. Weekly negative emotions WP *SD*	.22**	.02	.44**	.11**	-		
6. Weekly negative emotions *M*	.19**	−.31**	.09**	−.10**	.48**	-	
7. Meditation condition	−.03	.02	.001	−.08**	−.03	−.02	-

Note. Meditation condition was coded such that 0 = mindfulness meditation and 1 = loving-kindness meditation. *WP*, within-person

Table 3 Results of multilevel growth curve analyses examining changes in weekly variability in social connectedness across the course of a meditation intervention

Predictor	*B*	*p*	95% CI		*r*
			Lower	Upper	
Intercept	1.29	< .001	1.15	1.43	-
Week	−0.07	< .001	−0.10	−0.04	.17
Week^2	0.005	< .001	0.002	0.007	.14
Weekly social connectedness *M*	−0.10	< .001	−0.12	−0.08	.27
Condition	−0.02	0.79	−0.15	0.12	.01
Condition * week	−0.007	0.76	−0.05	0.04	.01
Condition * week^2	0.001	0.61	−0.01	0.01	.02

Note. *M*, mean levels. *CI*, confidence interval. *r* was calculated using the method used by Kashdan and Steger (2006): $r = \sqrt{(t^2/t^2 + df)}$

variability in social connectedness, positive emotions, or negative emotions.

Hypothesis 1, which proposed that people trained in mindfulness or loving-kindness meditation would experience reductions in weekly within-person variability in social connectedness across the course of the intervention, was examined first. Table 3 presents results of a multilevel growth curve analysis examining the trajectory of variability in social connectedness from week 1 to week 11 of the study. As expected, greater mean levels of social connectedness were associated with lower weekly variability in social connectedness. Even while including mean levels of social connectedness as a control variable, the linear and quadratic components for week were both statistically significant. Figure 1 displays the average change trajectory in weekly variability in social connectedness from week 1 to week 11 of the study. As shown in Fig. 1, and in support of hypothesis 1, participants experienced declines in variability in social connectedness soon after starting the meditation intervention. Those declines in variability in social connectedness then began to taper off towards the end of the intervention, at which point variability in social connectedness began to increase again. The main effect for condition was not

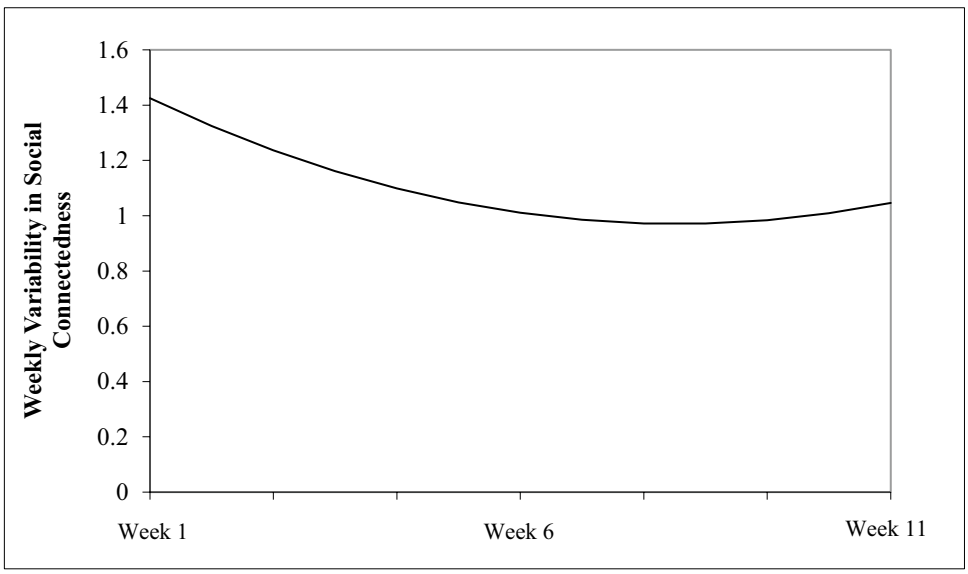

Fig. 1 Estimated growth trajectory of weekly variability in social connectedness across the course of the intervention

statistically significant, meaning that participants in the two meditation conditions did not report significant differences in variability in social connectedness across the course of the 11-week study. Moreover, the interactions between condition and the linear and quadratic components for week were both not significant, indicating that the patterns of change across the course of the intervention were not significantly different for participants who received training in mindfulness meditation and loving-kindness meditation.

Ancillary Table 1 presents results of an analysis that examined whether weekly mean levels of social connectedness moderated the association between time and fluctuations in social connectedness. As shown in Ancillary Table 1, mean levels of social connectedness did not significantly interact with the linear or quadratic component for week, suggesting that participants experienced a similar pattern of change across the course of the intervention regardless of the mean levels of social connectedness.

Next, hypotheses 2A and 2B were tested, or whether longitudinal changes in variability in positive and negative emotions mediated the link between week and reductions in variability in social connectedness. Mean levels in positive and negative emotions were also examined as mediators of the link between week and lower variability in social connectedness. Table 4 provides results of multilevel mediation analyses examining the indirect effect of week weekly negative emotions *SD* and *M* weekly social connectedness *SD*, while controlling for weekly mean levels of social connectedness. As shown in the top portion of the model, where week is a statistically significant predictor, participants experienced decreases in weekly variability in negative emotions across the course of the study, even controlling for weekly means in social connectedness. Condition did not moderate the association between week and variability in negative emotions, suggesting the declines variability in negative emotions were similar regardless of meditation condition. As shown in the bottom portion of Table 4, weekly variability in negative emotions, in turn, was associated with greater variability in social connectedness. In support of hypothesis 2A, participants reported lower weekly variability in negative emotions across the course of time, which then predicted lower variability in social connectedness, as the indirect effect of week → weekly negative emotions *SD* → weekly social connectedness *SD* was statistically significant (*estimate* = −0.005, *SE* = 0.003, 95% CI [−0.01, −0.001], *p* = 0.03). Additionally, the index of moderated mediation was not statistically significant (*estimate* = −0.002, 95% CI [−0.004, 0.004]), suggesting that participants in both meditation conditions similarly experienced reductions in negative affect variability, which then predicted reductions in social connectedness variability. Additionally, participants reported lower average levels of negative emotions across the course of the

Table 4 Results of multilevel mediation analyses examining negative affective variability as a mediator between meditation training and lower variability in social connectedness

				95% CI		
Outcome	Predictor	*B*	*p*	Lower	Upper	*r*
Weekly negative emotions *SD*	Intercept	0.30	< .001	0.27	0.32	-
	Week	−0.03	< .001	−0.04	−0.2	.12
	Week^2	0.002	< .001	0.001	0.003	.12
	Weekly social connectedness *M*	−0.03	< .001	−0.05	−0.01	.11
	Condition	−0.01	.46	−0.04	0.02	.05
	Condition × week	0.003	.30	−0.03	0.007	.02
Outcome	Predictor	*B*	*p*	Upper	Lower	*r*
Weekly negative emotions *M*	Intercept	0.52	< .001	0.47	0.57	-
	Week	−0.03	< .001	−0.04	−0.01	.10
	Week^2	0.002	< .001	0.001	0.0033	.10
	Weekly social connectedness *M*	−0.12	< .001	−0.13	−0.09	.27
Outcome	Predictor	*B*	*p*	Upper	Lower	*r*
Weekly social connectedness *SD*	Intercept	0.61	< .001	0.57	0.65	-
	Week	−0.07	< .001	−0.07	−0.04	.13
	Week^2	0.003	< .001	0.01	0.01	.11
	Weekly negative emotions *SD*	0.26	< .001	0.16	0.35	.12
	Weekly negative emotions *M*	0.17	< .001	0.09	0.25	.09
	Weekly social connectedness *M*	−0.13	< .001	−0.16	−0.10	.20

Note. The indirect effect of week weekly negative emotions *SD* weekly social connectedness *SD* was statistically significant (*estimate* = −.008, *SE* = .002, 95% CI [−.01, −.004], *p* = .002). The indirect effect of week weekly negative emotions *M* weekly social connectedness *SD* was also statistically significant (*estimate* = −.005, *SE* = .002, 95% CI [−.01, −.002], *p* = .02)

intervention, and greater average levels of negative emotion, in turn, predicted greater weekly variability in social connectedness, as the indirect effect of week → weekly negative emotions *M* → weekly social connectedness *SD* was also statistically significant (*estimate* = −0.005, *SE* = 0.002, 95% CI [−0.01, −0.002], *p* = 0.02).

Table 5 provides results of analyses examining the indirect effect of week → weekly positive emotions *SD* → weekly social connectedness *SD*, while controlling for mean levels of social connectedness (and including mean levels of positive emotions as a simultaneous mediator). As shown in the top portion of the model, the linear and quadratic components for week were both significant, suggesting participants experienced reductions in variability in positive emotions across the course of the study, which then tapered off towards the end of the study (i.e., a curvilinear pattern of change). Mean levels of social connectedness, condition, and the interactions between week and condition were not significantly associated with weekly variability in positive emotions. As shown in the bottom portion of Table 5, weekly variability in positive emotions was associated with greater weekly variability in social connectedness (even controlling for mean levels of weekly social connectedness), and the indirect effect of week → weekly positive emotions *SD* → weekly social connectedness *SD* was statistically significant (*estimate* = −0.009, *SE* = 0.002, 95% CI [−0.02, −0.003], *p* = 0.001), such that participants reported lower weekly variability in positive emotions across the course of time, which indirectly predicted lower variability in social connectedness. Additionally, the index of moderated mediation was not statistically significant (*estimate* = −0.001, 95% CI [−0.003, 0.003]), suggesting that the indirect effect of week on social connectedness variability via social connectedness variability was not significantly different for both meditation conditions. With respect to the indirect effect of week → weekly positive emotions *M* → weekly social connectedness *SD*, participants exhibited a quadratic pattern of change, whereby they experienced lower average levels of positive emotions soon after the start of the study, which then increased in the second half of the intervention (weeks 6–8), and after the end of the intervention (weeks 9–11). Regardless, average levels of positive emotions did not significantly predict weekly variability in social connectedness, thus rendering the indirect effect of week → weekly positive emotions *M* → weekly social connectedness *SD* non-significant (*estimate* = −0.004, *SE* = 0.003, 95% CI [−0.01, 0.009], *p* = 0.12).

Table 5 Results of multilevel mediation analyses examining positive affective variability as a mediator between meditation training and lower variability in social connectedness

				95% CI		
Outcome	Predictor	*B*	*p*	Upper	Lower	*r*
Weekly positive emotions *SD*	Intercept	0.40	< .001	0.37	0.43	-
	Week	−0.02	< .001	−0.03	0.01	.07
	Week^2	0.001	.007	0.0003	0.002	.06
	Weekly social connectedness *M*	0.01	.12	0.01	−0.02	.04
	Condition	−0.01	.86	−0.04	0.03	.01
	Condition × week	−0.01	.91	−0.01	0.01	.01
		B	*p*	Upper	Lower	*r*
Weekly positive emotions *M*	Intercept	1.80	< .001	1.71	1.87	-
	Week	−0.06	< .001	−0.07	−0.06	.17
	Week^2	0.01	< .001	0.003	0.006	.18
	Weekly social connectedness *M*	0.30	< .001	0.27	0.31	.50
		B	*p*	Upper	Lower	*r*
Weekly social connectedness *SD*	Intercept	0.61	< .001	0.57	0.65	-
	Week	−0.06	< .001	−0.07	−0.04	.14
	Week^2	0.004	< .001	0.002	0.005	.12
	Weekly positive emotions *M*	0.02	0.52	−0.03	0.07	.14
	Weekly positive emotions *SD*	0.50	< .001	0.42	0.58	.26
	Weekly social connectedness *M*	−0.17	< .001	−0.20	−0.13	.22

Note. The indirect effect of week weekly positive emotions *SD* Weekly social connectedness *SD* was statistically significant (*estimate* = −.009, *SE* = .002, 95% CI [−.02, −.003], *p* = .001). The indirect effect of week weekly positive emotions *M* weekly social connectedness *SD* was not statistically significant (*estimate* = −.001, *SE* = .001, 95% CI [−.004, .002], *p* = .52)

Discussion

Drawing on a randomized study of 224 midlife adults, this research explored the hypotheses that training in mindfulness or loving-kindness meditation would predict lower variability across the course of time, and that lower variability in positive and negative emotions would mediate this association. Results were generally consistent with predictions: participants who received instruction in mindfulness and loving-kindness meditation reported reduced variability in social connectedness across the course of the intervention, even controlling for mean levels of social connectedness. Additionally, and consistent with predictions, multilevel mediation analyses demonstrated that reductions in positive and negative affect variability (as well as lower average levels of negative emotions) could partially explain the association between time and lower variability in social connectedness.

The first and most important contribution of this research is that it demonstrates that mindfulness meditation and loving-kindness meditation not only are associated with benefits in social connectedness in terms of average levels; instead, mindfulness meditation and loving-kindness meditation are longitudinally associated with fewer social ups and downs in daily life. This is an important finding for two reasons. First, extensive evidence suggests that fluctuations in indicators of social functioning tend to predict maladaptive outcomes, even accounting for average levels of social functioning (Arriaga, 2001; Arriaga et al., 2006; Campbell et al., 2010; Girme, 2020; Girme et al., 2018). Because results demonstrated that training in meditation is associated with reductions in variability in social connectedness across time, the current research suggests that one of the ways in which meditation promotes well-being is because it is associated with fewer social ups and downs, in addition to enhanced overall social connectedness. Second, this research also provides fertile ground for future research to explore how meditation contributes to variability in other key social outcomes and experiences. To use one example, prior research has demonstrated that mindfulness — including mindfulness meditation — is associated with greater relationship satisfaction in the context of intimate relationships (Kappen et al., 2019; Karremans et al., 2017), yet prior research has not examined whether meditation may reduce variability in relationship satisfaction in daily life, and future research should explore this possibility.

One finding of note is the curvilinear pattern of change that was statistically significant in the growth curve analyses. In particular, participants experienced decreases in variability in social connectedness during the early intervention period, which then began to level off towards at the end of the intervention, and then increase again after the end of the intervention. What this suggests is that the reductions in variability that occurred during the intervention did not continue once participants stopped attending meditation classes. Instead, after the end of the intervention, during which many participants did not continue their daily meditation practice, their variability in social connectedness also returned to nearly baseline levels. As such, this curvilinear growth curve trajectory suggests that people may need to continue a daily meditation practice in order to maintain lower levels of variability in social connectedness.

This work also demonstrated that loving-kindness meditation was associated with fluctuations in affective experiences. Results suggested there was no difference between participants trained in mindfulness and loving-kindness meditation: both of them experienced reductions in variability in positive and negative emotions during the intervention period. As such, this research forges new ground in contemplative science by suggesting that it is not only mindfulness meditation that contributes to reductions in affective variability; loving-kindness meditation, too, is associated with fewer ups and downs in affect across the course of time in everyday life.

It is important to note the possibility for bi-directionality between change in affective variability (both positive and negative) and change in variability in social connectedness in the mediation analyses. Although this study utilized a rigorous longitudinal design, the mediation analyses ultimately examined the co-occurrence of change trajectories across the course of the intervention. Indeed, it is plausible that reductions in variability in social connectedness may contribute to lower variability in and mean levels of positive or negative emotions, in addition to these emotions contributing to lower variability in social connectedness. Social connectedness is a robust contributor to daily mood (e.g., Reis et al., 2000), meaning these mediation analyses should be considered a first step in illuminating the mechanisms by which meditation training is associated with reduced variability in social connectedness across the course of time.

Limitations and Future Research

All of these findings should be considered in light of a key limitation of this work: the intervention study upon which we drew to test these hypotheses did not include a control condition of participants who were not trained in meditation. Because of this, it remains a possibility that participants in both conditions experienced changes in affective and social variability as a result of a placebo-like process, and that they would not out-perform participants randomly assigned to an active control condition (e.g., Karremans et al., 2020). With this note of caution in mind, future

researchers should follow up on these suggestive findings using an intervention study with a control group, in order to establish meditation as the active ingredient for change in social connectedness variability. Similarly, although this research drew upon 3 weeks of daily data after participants stopped attending meditation training, it is possible that different patterns of change would have emerged after the 3 weeks examined here, such as 4–6 weeks after the meditation intervention. Another important limitation of this work is that participants were somewhat homogenous in terms of demographic characteristics that may influence experiences related to affect and social relationships. For instance, age, socioeconomic status, and ethnic background may all play a role in participants' daily social and affective experience; because participants in this study were middle-aged, predominantly middle class, and predominantly White, it is not clear whether these results would generalize to participants from other demographic backgrounds.

Additionally, one other important direction for future research is examining how changes in daily experiences of state mindfulness may play a role in the processes we examined. Meditation interventions (especially mindfulness meditation) presumably influence the extent to which people are mindful in daily life, and these daily increases in mindfulness may be the proximal theoretical reason why meditation is associated with lower variability in affect and/or social connectedness (e.g., Keng et al., 2016). Although daily variation in state mindfulness was not assessed in this research, future research should examine whether daily mindfulness is indeed a proximal mechanism explaining why meditation interventions are associated with reductions in affective and relational variability. Despite these limitations, this research provides evidence that meditation training may be one way in which people may smooth the ups and downs of their feelings of social connectedness in daily life.

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Author Contribution BPD: formulated the hypotheses, conducted data analyses, and wrote the paper. PVC: collaborated in writing this manuscript, and played a key role in collection of these data. BLF: designed the study from which these data are derived, oversaw data collection, and collaborated on the writing of this manuscript.

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Data Availability All measures, data analytic syntax, and data used for this manuscript are provided in full on the corresponding OSF page for this study here: https://osf.io/kxwn5/?view_only=c6bec19e919f47ae868e1d410442bf2c.

Declarations

Ethics Statement All study procedures were approved by the Institutional Review Board of the University of North Carolina at Chapel Hill.

Informed Consent Statement All participants gave their consent to participate prior to enrolment in this study.

Conflict of Interest The authors declare no competing interests.

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