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ORIGINAL PAPER

For Whom Do Meditation Interventions Improve Mental Health Symptoms? Looking at the Roles of Psychological and Biological Resources over Time

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Abstract

Objectives Engaging in meditation seems to be an effective manner of bettering psychosocial health. Although these findings hold for most people, individual differences may affect who gets greater gains from meditation. Psychological (i.e., resilience, spirituality) and biological (i.e., cardiac vagal tone, oxytocin) personal resources may work individually or synergistically to catalyze meditation-related improvements in mental health, such as increased positive (well-being) and decreased negative (depression) mental health symptoms.

Methods A community-based sample of 210 adults ($mode_{age} = 35$ years; 61.86% female) were recruited and randomly assigned to either mindfulness ($n = 107$; 51.2%) or loving-kindness ($n = 102$; 48.8%) meditation conditions (1 missing). The study lasted 18 months, starting with baseline measures, succeeded by a 6-week meditation intervention, and follow-up assessments every 3 months.

Results The fixed effect of resilience was significant, as was the interaction between resilience and time, indicating different mental health symptom trajectories during and after a meditation intervention based on resilience.

Conclusions Participants low in resilience tended to have the greatest gains (increased subjective well-being and decreased depressive symptoms) following a meditation intervention, yet these gains were not maintained 18 months following the intervention. Those high in resilience did not show mental health gains following a meditation intervention but did have higher subjective well-being symptoms 18 months following the intervention indicating that they may have experienced delayed gains.

Keywords Subjective well-being · Depression · Resilience · Spirituality · Oxytocin · Cardiac vagal tone

Meditation practices, such as mindfulness and loving-kindness, are increasingly popular in the USA. A 2014 survey of more than 35,000 Americans found that 40% reported that they meditated at least once in the last week (Masci & Hackett, 2018). Importantly, these meditation practices have been associated with improved psychological health. In a review of five randomized control trials (RCTs) that used both non-movement meditation practice and physical exercise to differentiate direct effects of these practices on physical and psychosocial outcomes (representing a total $N = 325$), the authors concluded that meditation was more effective than exercise for improving psychosocial outcomes, such as anxiety, and perceived stress (Edwards & Loprinzi, 2018). Another review of 47 RCTs (representing a total $N = 3515$) found that mindfulness meditation improved depression and anxiety, but they did not find evidence that this improvement was above and beyond that of other active treatment (i.e., drugs, exercise, behavioral therapies; Goyal et al., 2014). Another study found that depressive symptoms were reduced following loving-kindness meditation

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(Fredrickson et al., 2008). Overall, there is some evidence suggesting that meditation can alleviate some markers of negative mental health, such as perceived stress, anxiety, and depressive symptoms.

Historically, mental health had been operationalized as the absence of mental illness. If one does not experience disorders such as depression, anxiety, and posttraumatic stress, then they were assumed to be mentally healthy. More recently, however, it has been posited that mental health extends beyond the absence of mental illness (Keyes, 2002, 2005). In addition to a lack of mental illness, having subjective well-being is necessary for complete mental health. Researchers in this area argue for mental health promotion and protection based on the initial evidence that losses in positive mental health are related to increases in mental illness; therefore, mental illness prevention may be tackled more effectively by maintaining, or even increasing, experiences of positive mental health, such as subjective well-being (Keyes, 2005; Keyes et al., 2010). Subjective well-being has been conceptualized as comprising two components: hedonic (centering on pleasure attainment and pain avoidance) and eudaimonic (centering on self-realization and fulfillment of purpose in life) (Ryan & Deci, 2001). Building from this view, a multi-dimensional well-being model has been identified that includes emotional (stemming from hedonic), social, and psychological (stemming from eudaimonic) well-being (Keyes, 2002). Both mindfulness and loving-kindness meditation practices were associated with improved emotional well-being, assessed as day-to-day positive emotions increases (Fredrickson et al., 2017). Though not overwhelming, current evidence thus suggests that meditation has the potential to influence both positive and negative aspects of mental health. It is unclear whether meditation has mental health benefits for everyone and whether there are any individual resources that may catalyze its benefits.

One potential personal resource is resilience. Though debate continues regarding resilience's definition (Herrman et al., 2011), broad definitions include positive adaptation despite adversity (Wald et al., 2006). Novel conceptualizations argue that resilience is an iterative (i.e., influenced by past experiences) dynamic coping process such that one's resilience can increase as the result of positive adaptation (Herrman et al., 2011; Hill et al., 2018). Resilience has been posited by clinical neuroscientists as a novel and impactful future treatment target for mental disorders, such as depression (Pfau & Russo, 2015) and has been associated with greater subjective well-being in adults (Mayordomo et al., 2016). Meditation has been found to increase resilience. Following a 4-day intervention of either meditation or control relaxation, participants from both groups reported increased resilience post-intervention, but only the meditation group maintained their increases in resilience 3 months later (Kwak et al., 2019). As resilience reflects one's capacity to adapt well and meditation may increase resilience, more resilient individuals may glean and maintain greater mental health benefits from meditation interventions.

Spirituality reflects the personal search for connection with a larger sacredness or a transcendent entity (Piedmont, 1999). It is often accompanied with feelings of interconnectedness with others and presence of higher meaning. A large body of research has shown that individual differences in spirituality are associated with greater well-being (Kashdan & Nezlek, 2012; Piedmont, 1999; Van Cappellen et al., 2016a, b). People reporting greater spirituality also more frequently practice meditation in everyday life (Masci & Hackett, 2018) and they may also be more attuned and receptive to a meditation intervention. However, one previous study failed to find that daily spiritual experiences moderated the reduction in depressive symptoms following a mindfulness-based meditation intervention (Greeson et al., 2015). With this, those high in spirituality may reap greater mental health benefits from initiating a meditation practice.

A potential biological predictor of mental health is cardiac vagal tone (CVT, Kok et al., 2013), a marker of autonomic nervous system functioning. Individual autonomic nervous system functioning consists of sympathetic—increased arousal—responses and parasympathetic—return to homeostasis—responses that fluctuate based on internal and external stressors (Bernston et al., 1997). More generally, CVT reflects efficient biological recovery from stress (Gillie & Thayer, 2014). In a review of randomized control trials that targeted vagal tone biofeedback (Gevirtz, 2013), training cardiovascular homeostatic reflexes resulted in greater physical health outcomes (e.g., lung function, pain, infant birth weight), decreased pathopsychological symptoms (e.g., depression, phobias, anxiety), improved sleep, and improved athletic performance (golf and dance scores). In the model of neurovisceral integration, Thayer and Lane (2000) and Thayer et al. (2009) argue that these processes are highly individualized. Specifically, differences in CVT between individuals are indicative of individual differences in neural flexibility and more adaptive, goal-directed cognitive, affective, and behavioral responses. Engaging in Zen meditation was associated with an increased parasympathetic index of heart rate variability in high trait anxious individuals, which the authors claimed indicated vagal facilitation (Murata et al., 2004). This study team's past work showed individuals differences in CVT to predict the degree to which people show gains in positive emotion when socializing (Isgett et al., 2017) and in response to a 6-week loving-kindness meditation workshop (Kok et al., 2013). Therefore, it is of interest to look into individuals' CVT

and its influence on positive and negative mental health trajectories following a meditation intervention.

Oxytocin, OT, is a polypeptide originating in the hypothalamus that has received increasing attention from psychologists for its role in many social affiliative processes, such as trust, empathy (Kumsta & Heinrichs, 2013). In one randomized double-blind study, this study team found that intranasal administration of synthetic OT, compared to a placebo, increased male adults' spirituality controlling for religiosity, which in turn increased the positive emotions they felt (assessed with both explicit and implicit measures) when introduced to a 20-min mindfulness or loving-kindness meditation (Van Cappellen et al., 2016a, b). Individual differences in tonic levels of endogenous OT also predict the degree to which people show gains in positive emotion when socializing (Isgett et al., 2017). It was hypothesized that people with higher levels of endogenous OT may derive more of the positive mental health benefits from meditation.

The presence of psychological (i.e., resilience, spirituality) and biological (i.e., CVT, OT) personal resources have individually been empirically linked to adaptive outcomes. Psychological and biological factors may also work synergistically to amplify and sustain positive biopsychosocial outcomes, though biological systems do not necessarily bear a one-to-one mapping onto to psychological systems (Cacioppo & Tassinary, 1990). It has been hypothesized that resilience and CVT have a synergistic interaction. Results, however, reflected two main effects rather than the predicted synergistic interaction effect (Souza et al., 2007, 2013). Although the hypothesized synergy between resilience and CVT was not evident following a laboratory stressor, here, the interaction following a positive behavior intervention was tested. Furthermore, the OT system and spirituality appear to be connected in meaningful ways, with preliminary evidence suggesting that increases in OT are attended by increases in spirituality (Holbrook et al., 2015; Van Cappellen et al., 2016a, b). This positive association between the two lends to the hypothesis that their synergy may serve to best predict for whom learning meditation improves mental health symptoms, especially in an environment meant to catalyze positive change. Empirical evidence also suggests that each of these individual differences may not be stable over time, but rather may change over time and even grow as a result of engaging in meditation. Researchers found that meditation increases resilience (Kwak et al., 2019) and spirituality (Matiz et al., 2018). Third, cardiac vagal tone has been shown to increase more during meditation than other relaxing behaviors (Ditto et al., 2006) and also to increase following a 6-week loving-kindness meditation intervention (Kok et al., 2013). Finally, one study found that a mindfulness meditation session increased salivary OT levels (Bellosta-Batalla et al., 2020). For these reasons, it is pertinent to explore how individual differences in these characteristics interact with each other and with time.

The present overarching study was originally designed to investigate personal resources that predict and support midlife lifestyle change. Midlife adults were targeted in this study because, despite representing 20% of Americans (United States Census Bureau, 2010), this period of life tends to be understudied as compared to younger and older periods. However, evidence suggests that well-being is u-shaped across lifespan, and generally lowest in midlife (Blanchflower & Oswald, 2008), making this age group an area of concern. Midlife is also a pivotal period in the human lifespan that can influence later-life trajectories of physical health, cognitive functioning, and well-being, as examples (Lachman et al., 2015). The current analyses were designed to identify the midlife subgroups for whom meditation practices may yield the greatest gains in mental health.

Methods

Participants

Data from this larger, NIH-supported study (R01CA170128) have been reported on elsewhere (Fredrickson et al., 2021; Rice & Fredrickson, 2017). Participants were recruited North Carolina's Durham and Orange counties via paper and electronic advertisements. Participant inclusion requirements included being between 35 and 65 years old with no prior history of meditation, fluent in written and spoken English, interested healthy lifestyle changes and learning meditation, and daily internet access. This longitudinal study was advertised as examining wellness behaviors and participants received monetary compensation for their participation, as reported elsewhere (Fredrickson et al., 2017, Study 2). Due to variables used for the present study, the analytic sample consisted of 210 participants ($n = 129$ (61.72%) self-identified as female; $M_{age} = 48.53 \pm 8.95$ years; $mode_{age} = 35$ years). Most participants reported being White or Caucasian ($n = 160$; 76.56%) followed by Black or African American ($n = 37$; 17.70%), Asian ($n = 11$; 5.26%), and American Indian or Alaskan Native ($n = 1$; 0.48%). Participants also reported being Hispanic or Latino ($n = 8$; 3.83%) or Not Hispanic or Latino ($n = 201$; 96.17%). Gender, age, race, and ethnicity were all missing one response.

Procedure

All procedures were approved by the Institutional Review Board of the University of North Carolina at Chapel Hill. Following completion of informed consent, participants were randomly assigned to either one of two meditation conditions: mindfulness ($n = 107$; 51.2%) or loving-kindness

($n = 102$; 48.8%) Condition data was missing for one participant. This larger, NIH-supported study's aim was to investigate the role of positive emotions in facilitating successful lifestyle change. The mindfulness (MM) and loving-kindness (LKM) meditation interventions were identical in format, comprised of 1-h weekly classes in small groups for 6 weeks. In addition, all participants were instructed to cultivate a daily meditation practice, realistically benchmarked at 3–5 sessions per week. They received written resources and five 20-min guided meditation tracks to support their home practice. The content of each intervention (MM and LKM) has been described in detail elsewhere (Fredrickson et al., 2017), so only the main features are described here. Each intervention was developed in collaboration with meditation experts to be secular while still retaining the core psychological qualities of the traditional practices. Both courses involved developing an open and nonjudgmental attitude. For MM, participants were instructed to direct their attention toward the contents of consciousness within the present moment and to do so in a decentered (less personalized) way. Progressively, over the 6 weeks, the targets of consciousness expanded, with practice directed toward breathing and hearing (week 1), the body (week 2), emotions (week 3), thoughts (week 4), and choiceless awareness (week 5), with week 6 reserved for review and integration. For LKM, participants were instructed to self-generate warm and friendly feelings toward various social targets. They were also instructed to direct their attention toward the physical sensations in the heart region. Progressively, over 6 weeks, the social targets of loving-kindness expanded, with practice directed toward a loved one (week 1), oneself (week 2), an acquaintance (week 3), a difficult person (week 4), and all beings (week 5), with week 6 reserved for review and integration. The full study length was 18 months, starting with baseline measures, a 6-week meditation training phase as described above, and a combination of in-lab and online follow-ups every 3 months (see Supplemental Fig. 1). Participants completed valid and reliable self-report measures along with biological measures throughout the study period (see the "Measures" section for further details and Supplemental Fig. 1 for an assessment schedule). Of note, subjective well-being was only collected at three main time points (baseline, post-intervention, and final, 18-month follow-up), whereas depressive symptoms were collected at all study time points.

Measures

Resilience was measured via the 14-item Ego-Resiliency Scale (ER89; Block & Kremen, 1996). Participants responded to items such as "I quickly get over and recover from being startled," on a scale ranging from 1 (*does not apply at all*) to 4 (*applies very strongly*). Item responses were added together to create a resilience score. A higher aggregate score indicated higher levels of resilience. Internal consistency values for resilience across time points ($\alpha = 0.97$) and for each time point ($\alpha s = 0.77$–0.84) were acceptable to excellent (DeVellis, 2017).

Spirituality was measured using the Universality and Connectedness subscale from the Spiritual Transcendence Scale (Piedmont, 1999). Spirituality here is defined as the tendency to orient oneself toward a larger transcendent reality that binds all things into a unitive harmony. It reflects the personal search for connection with a larger sacredness. The subscale Prayer Fulfillment was not included in this study because this measure of spirituality is not clearly distinct from religiosity. To report spirituality, participants endorsed how much they agree with nine statements, such as "I believe that on some level my life is intimately tied to all of humankind" and "All life is interconnected," on a scale from 1 (*strongly disagree*) to 7 (*strongly agree*). Item responses were aggregated to create a spirituality score with a higher score indicating higher spirituality. Internal consistency values for spirituality across time points ($\alpha = 0.98$) and for each time point ($\alpha s = 0.89$–0.94) were excellent.

Cardiac vagal tone was indexed via respiratory sinus arrhythmia (RSA). Electrocardiogram measurements were collected for each participant using a bipolar configuration and pneumatic bellows collected respiration period and amplitude. Heart rate was recorded continuously at a sampling rate of 1000 Hz. Data were cleaned offline. Custom software (James Long Company; Caroga Lake, NY) utilizing modified Grossman peak-to-valley method (Grossman, 1983) with resampling every 125 ms was used to calculate RSA. A tonic RSA score for each person was computed from an average over a 5-min resting period. Measurements were collected at baseline, post-intervention (3-month), and 18-month follow-ups. Cardiac vagal tone showed greater between-person than within-person variance (ICC = 0.53); therefore, average CVT for each participant was calculated and used as a time invariant covariate. Higher scores indicate greater, more adaptive cardiac vagal tone.

Oxytocin (OT) was calculated using urine samples. Participants provided a 60-min controlled urine sample (participants voided their bladder upon arriving to the lab, drank 12 oz. of water and then gave a urine sample 60 min later). Using the urine samples, an OT value was measured as pg/mg creatinine at each timepoint. From there, average OT was calculated across time points for each participant due to between-subjects differences (ICC = 0.40) and lack of variation over the study period ($\gamma_{01} = -0.45$, $SE = 0.9055$, $t(357) = -0.82$, $p = 0.41$). Higher scores indicate higher OT levels, which is adaptive.

Participants completed two psychometric assessments to measure subjective well-being and depressive symptoms. Individual aggregate scores at each time point were used

to test for whom a meditation intervention would benefit most. The 14-item Mental Health Continuum – Short Form (Keyes, 2009) was used to assess subjective well-being. Participants reported how often during the past week she/he felt emotional, social, and psychological well-being. Responses ranged from 0 (*never*) to 5 (*every day*) on a 6-item Likert scale. Aggregate scores were calculated for each time point with higher scores reflecting greater subjective well-being. The internal consistency values observed in this study for subjective well-being across time points ($\alpha = 0.97$) and for each time point ($\alpha s = 0.91$–0.94) were regarded as excellent (Cronbach, 1946). The Center for Epidemiological Studies – Depression scale (CES-D) (Radloff, 1997) assess depressive symptoms over the past 7 days using 20 items (e.g., "I was bothered by things that usually don't bother me" and "I felt like everything I did was an effort") on a scale from 0 (*never*) to 3 (*almost always*). Aggregate scores for each time point were calculated with higher scores reflecting more depressive symptoms. The internal consistency values observed in this study for depressive symptoms across time points ($\alpha = 0.98$) and for each time point ($\alpha s = 0.91$–0.93) were regarded as excellent.

Data Analyses

The distributional properties of all outcome measures were examined prior to primary analyses. Bivariate associations between study variables were also examined averaged across time. Subjective well-being and depressive symptom trajectories were assessed using multiple multivariate linear mixed effects models to account for repeated measures nested within individual participants, differences between participants at baseline (random intercepts), and different mental health symptom trajectories (random linear and quadratic time effects) (Fitzmaurice et al., 2011). Nonlinear trajectories were assessed based on an initial period of behavior change effort following by 15 months of follow-up with varying efforts to maintain behavior change. Meditation intervention condition (mindfulness or loving-kindness) and time spent meditating following the intervention phase until the 18-month follow-up (average sum of minutes each week between time points) were associated with the dependent variables. Three months following the intervention, individuals spent about 30 min a week meditating (range 0–370 min/week). Participants reported similar behavior until the 18-month follow-up where participants meditated 10 min a week on average (range 0–480 min/week). Approximately 72% of participants reported meditating 3 months after the intervention whereas only 56% reported any meditation at the 18-month follow-up. Neither condition, $\gamma_{01} = -2.01$, $SE = 1.90$, $t(176) = -1.06$, $p = 0.29$; $\gamma_{01} = -0.11$, $SE = 1.12$, $t(210) = -0.10$, $p = 0.92$, nor time spent meditating, $\gamma_{02} = 0.02$, $SE = 0.01$, $t(94) = 1.53$, $p = 0.13$; $\gamma_{02} = -0.004$, $SE = 0.002$, $t(790) = -1.72$ $p = 0.09$, had main effects on subjective well-being nor depressive symptoms, respectively. Therefore, these potential covariates were dropped from all proceeding models. Time, resilience, spirituality, and OT were mean-centered prior to model building. Time was mean-centered to minimize the correlation between time and quadratic time. All other independent variables were mean-centered to create more interpretable estimates. Resilience, CVT, and OT were also rescaled, by 1000, 100, and 100, respectively, in Tables 1 and 2 so that parameter estimates were within a reasonable range. To create models that were comparable, cases missing values for any personal resource were deleted listwise. This left the final analytic sample 210 participants.

Model building for each outcome began with an unconditional model (only including time and time-squared terms) then proceeded with individually estimating main effects of each personal resource over time (simple and interactive effects with time) to test hypothesis 1. Next, predicted synergistic effects between psychological and biological variables were added to a model including simple effects of those resources to test hypothesis 2. Interaction models were then graphically depicted based on different levels of resilience or spirituality (quantified as relatively high, moderate, or low sample quartile ranges). A chi-squared difference test for nested models was used to compare model fit for the unconditional models against resource interaction models. Data were analyzed using SAS statistical software (v 9.4; SAS Institute Inc, Cary, NC). Criterion for statistical significance was set at 0.05 a priori.

Results

Descriptive Statistics and Preliminary Analyses

Central tendencies and dispersion with correlations among study variables can be found in Supplemental Table 1. Subjective well-being symptoms were significantly, positively associated with resilience ($rs = 0.50$–0.63, $ps < 0.01$) and spirituality ($rs = 0.25$–0.30, $ps < 0.01$) at baseline, post-intervention, and the 18-month follow-up. Depressive symptoms were also significantly, though negatively, correlated to resilience scores at each measured time point ($rs = -0.56$ to -0.32, $ps < 0.01$). Depressive symptoms and spirituality scores were significantly correlated at baseline ($r = -0.14$, $p = 0.05$), but not at post-intervention or the 18-month follow-up ($rs = -0.13$ and -0.08, $ps = 0.09$ and 0.27, respectively). Neither synergistic personal resources—resilience and CVT nor spirituality and OT—related to one another at any study time point ($ps > 0.05$) minimizing the potential for multicollinearity in further models.

Table 1 The effects of psychological and biological effects with time on positive and negative mental health symptom trajectories

Effect	Parameter	Subjective Well-being		Depression	
		Resilience, CVT, and time interaction	Spirituality, OT, and time interaction	Resilience, CVT, and time interaction	Spirituality, OT, and time interaction
Fixed effects					
Status at posttest, π_{0i}					
Intercept	γ_{00}	49.62*** (0.94)	50.12*** (0.98)	31.29*** (0.51)	31.27*** (0.55)
Resilience	γ_{01}	75.01*** (14.21)		−35.58*** (5.33)	
CVT	γ_{02}	39.22 (33.61)		−18.95 (18.12)	
Spirituality	γ_{03}		30.00*** (7.91)		−16.91*** (3.38)
OT	γ_{04}		−31.60 (29.15)		2.35 (15.56)
Resilience*CVT	γ_{05}	400.82 (555.56)		−25.26 (217.36)	
Spirituality*OT	γ_{06}		5.67 (237.73)		235.94** (90.12)
Linear rate of change, π_{1i}					
Time	γ_{10}	0.31** (0.11)	0.34** (0.11)	0.02 (0.07)	−0.01 (0.07)
Resilience*time	γ_{11}	0.92 (1.94)		−0.76 (1.27)	
Spirituality*time	γ_{12}	1.26 (3.84)		−1.97 (2.64)	
CVT*time	γ_{13}		0.75 (1.01)		0.63 (0.67)
OT*time	γ_{14}		−3.84 (3.32)		0.68 (1.98)
Resilience*CVT*time	γ_{15}	18.64 (65.77)		−23.39 (46.89)	
Spirituality*OT*time	γ_{16}		−28.81 (29.05)		52.64** (19.15)
Quadratic rate of change, π_{2i}					
Time^2	γ_{20}	−0.16* (0.07)	−0.21** (0.07)	0.05 (0.03)	0.06 + (0.03)
Resilience*time^2	γ_{21}	3.50** (1.20)		−1.02 + (0.56)	
Spirituality*time^2	γ_{22}	−2.61 (2.52)		−1.78 (1.14)	
CVT*time^2	γ_{23}		0.15 (0.66)		0.14 (0.31)
OT*time^2	γ_{24}		4.65* (2.16)		0.12 (0.93)
Resilience*CVT*time^2	γ_{25}	−9.75 (45.29)		13.62 (20.41)	
Spirituality*OT*time^2	γ_{26}		31.67 (19.46)		−4.66 (8.72)
Random effects					
Variance components					
Level 1 (residual)	σ^2_ε	32.69***	22.68***	27.04***	26.85***
Level 2 (intercept)	σ^2_0	65.05***	97.37***	42.20***	53.24***
Level 2 (time)	σ^2_1	0.16	0.46$^+$	0.22*	0.15$^+$
Level 2 (time^2)	σ^2_2	0.05	0.21**	0.02	0.03$^+$
Goodness-of-fit					
Deviance		2978.76	3044.90	8099.72	8136.37
Δ^2		111.46***	45.31***	81.10***	44.45***
Δdf		3	3	3	3

Each fixed effect value is a parameter estimate with its standard error. The intercept parameter estimate (γ_{00}) depicts the average subjective well-being score at midpoint of the study (9 months) at average scores for each independent variable in the model. All other fixed effect estimates indicate the change from the intercept for each independent variable

$^+p < .10$

$^*p < .05$

$^{**}p < .01$

$^{***}p < .001$

Subjective Well-being Symptom Trajectories

Unconditional linear and quadratic individual longitudinal trajectories were fit for subjective well-being symptoms across the 18-month study period. From the significant main fixed effect of linear, $t(217) = 2.72$, $p < 0.01$ and

Table 2 Estimated subjective well-being and depressive symptom score changes and standard error across major study time points for low, moderate, and high resilience and oxytocin participants

	Baseline to post-intervention (intervention effects)	Baseline to 18-month follow-up (maintained effects)	Post-intervention to 18-month follow-Up (delayed effects)
Subjective well-being			
Low resilience	+4.31 (1.15)***	+2.24 (1.16)[a]	−2.07 (1.15)[b]
Moderate resilience	+2.25 (0.80)**	+2.38 (0.79)**	0.13 (0.79)
High resilience	0.19 (1.14)	2.52 (1.14)*	2.33 (1.11) *
Low oxytocin	+4.40 (1.61)***	+3.75 (1.22)**	−0.64 (1.17)
Moderate oxytocin	+2.45 (0.81)**	+2.44 (0.87)**	−0.01 (0.83)
High oxytocin	+0.49 (1.23)	+1.13 (0.34)	0.63 (1.26)
Depression			
Low resilience	−2.10 (0.76)**	−1.03 (0.87)	+1.01 (0.86)
Moderate resilience	−1.01 (0.54) [c]	−0.52 (0.59)	−0.02 (0.60)
High resilience	+0.07 (0.79)	−0.01 (0.86)	−1.05 (0.85)

Low and high scores calculated as ± 1*SD* from mean, moderate = sample mean

[a] $p = 0.054$ indicating marginal significance

[b] $p = 0.074$ indicating trending effect

[c] $p = 0.059$ indicating marginal significance

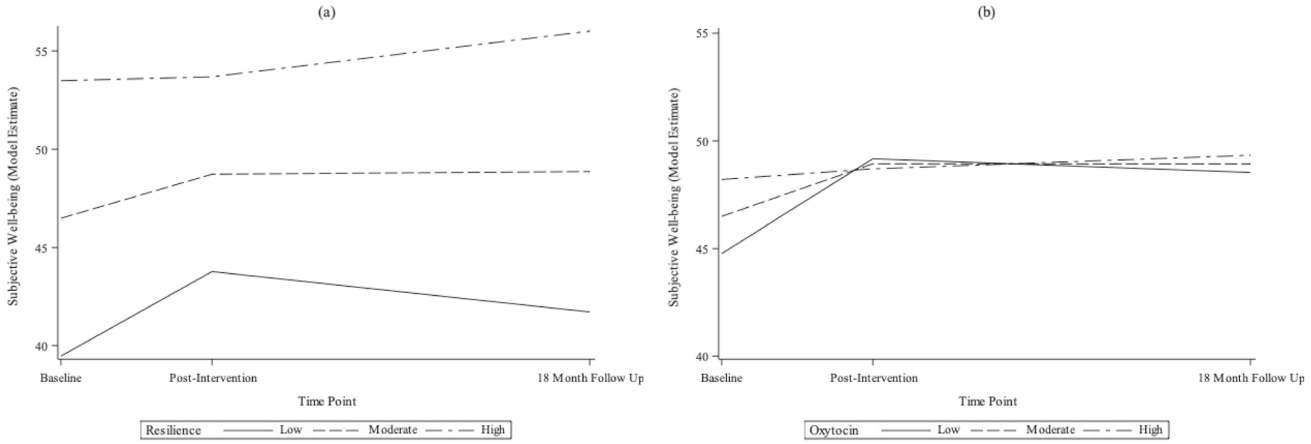
quadratic, $t(217) = -2.50$, $p = 0.01$, time, well-being increased over the study period in a parabolic manner (see Supplemental Fig. 2a and Supplemental Table 2). Therefore, a quadratic mean structure for subjective well-being was used in all subsequent conditional models. Individual subjective well-being varied at baseline, $Z = 7.18$, $p < 0.01$, and individuals differed in quadratic subjective well-being trajectories, $Z = 1.92$, $p = 0.03$, as seen in Supplemental Fig. 2b. Conditional models were proceeded with in an effort to further explain the interpersonal heterogeneity in subjective well-being trajectories.

Hypothesis 1 for subjective well-being was then tested in four separate models, one for each resource including their simple effects (across time points) and interaction effects with time (associations as a function of time). Resilience demonstrated significant simple, $t(214) = 5.25$, $p < 0.01$, and quadratic time interactive, $t(214) = 2.90$, $p < 0.01$, effects on subjective well-being symptoms (see Supplemental Table 2). For a breakdown of the resilience and quadratic time interaction, see Table 2. Cardiac vagal tone had no significant effect on subjective well-being symptoms. Spirituality demonstrated significant simple effect on subjective well-being symptoms, $t(214) = 3.33$, $p < 0.01$. Oxytocin demonstrated a significant quadratic time interactive effect on subjective well-being symptoms, $t(214) = 2.03$, $p < 0.05$. These findings indicate that effects of resilience and oxytocin on subjective well-being were partially a function of time which provides some support of hypothesis 1 (see Fig. 1a and b, respectively).

Two final models also contained potential synergistic effects and time interactions to test hypothesis 2 for subjective well-being. In the first model, resilience demonstrated significant simple, $t(208) = 5.28$, $p < 0.01$, and quadratic time interactive, $t(208) = 2.92$, $p < 0.01$, effects on subjective well-being symptoms. No synergistic effects between resilience and cardiac vagal tone were found, though individuals remained significantly different at baseline, $Z = 6.34$, $p < 0.01$. Quadratic trajectories were no longer significantly random, $Z = 0.77$, $p = 0.22$. In the next model, spirituality still demonstrated a significant simple effect, $t(208) = 3.79$, $p < 0.01$. Oxytocin significantly interacted with quadratic time, $t(208) = 2.16$, $p < 0.05$, on subjective well-being symptoms. Here, individuals remained significantly different at baseline, $Z = 7.16$, $p < 0.01$, and had different quadratic trajectories, $Z = 2.51$, $p < 0.01$. Conditional models were each better fitting than the unconditional model, $\Delta\chi^2$ *s* (9, 208) = 45.31–111.46, *ps* < 0.01 (see Table 1), mainly from resilience and spirituality contributing to subjective well-being symptom variance.

Depressive Symptom Trajectories

Unconditional linear and quadratic individual longitudinal trajectories were fit for depressive symptoms across the study period. There was a nonsignificant fixed effect of linear time, $t(1016) = 0.06$, $p = 0.95$. Additionally, the fixed quadratic effect of time was nonsignificant, $t(1016) = 1.59$, $p = 0.11$, meaning that there was a nonsignificant change in depressive symptoms over time across participants (Supplemental Fig. 3a and Supplemental Table 3). Although the overall quadratic effect was not significant, individual depressive symptoms varied significantly at baseline,



Note. Participants were divided into low, mean, and high for illustrative purposes only. Analyses were based on continuous data.

Fig. 1 Subjective well-being symptom trajectories across study period for low, moderate, and high resilience (**a**) and oxytocin (**b**) participants

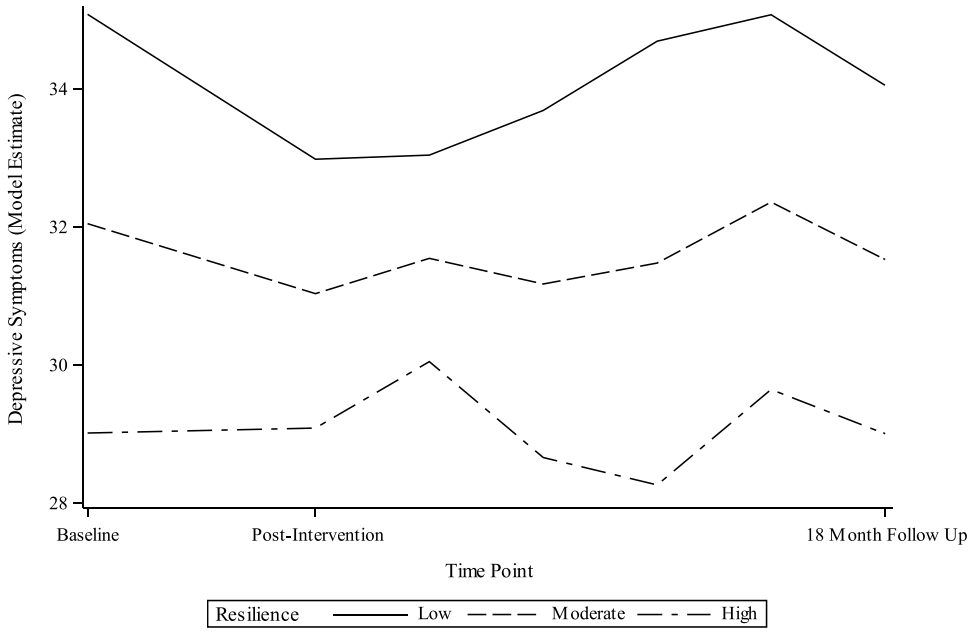


Fig. 2 Depressive symptom trajectories across study period for low, moderate, and high resilience participants

Note. Participants were divided into low, mean, and high for illustruative purposes only. Analyses are based on continuous data.

$Z = 8.97$, $p < 0.01$, and individual linear trajectories also varied significantly from one another, $Z = 2.08$, $p = 0.02$, as seen in Supplemental Fig. 3b. Due to the random effects, conditional models were proceeded with in an effort to explain significant individual differences in longitudinal trajectories. Characteristic by time interactions were also added to address hypothesis 1 regarding biopsychological characteristics associating with depressive symptom trajectories. In four separate models, each personal resources' simple and time interactive effects (linear and quadratic) were probed (see Supplemental Table 3). Resilience showed significant simple, $t(1013) = -6.78$, $p < 0.01$, and trending quadratic time interactive, $t(1013) = -1.73$, $p = 0.08$, effects on depressive symptoms. This indicates that the effect of resilience on depressive symptoms is partially a function of time (see Fig. 2 and Table 2). Spirituality demonstrated significant simple negative effect on depressive symptoms, $t(1013) = -4.89$, $p < 0.01$. Neither CVT nor oxytocin exhibited significant fixed effects on depressive symptoms.

Two final depression models contained potential synergistic effects and time interactions. In the first model, resilience still demonstrated significant simple, $t(1007) = -6.68$, $p < 0.01$, and trending quadratic time interactive, $t(1007) = -1.82$, $p = 0.07$, effects on depressive symptoms. No synergistic effects between resilience and cardiac vagal tone were found. Participants remained significantly different

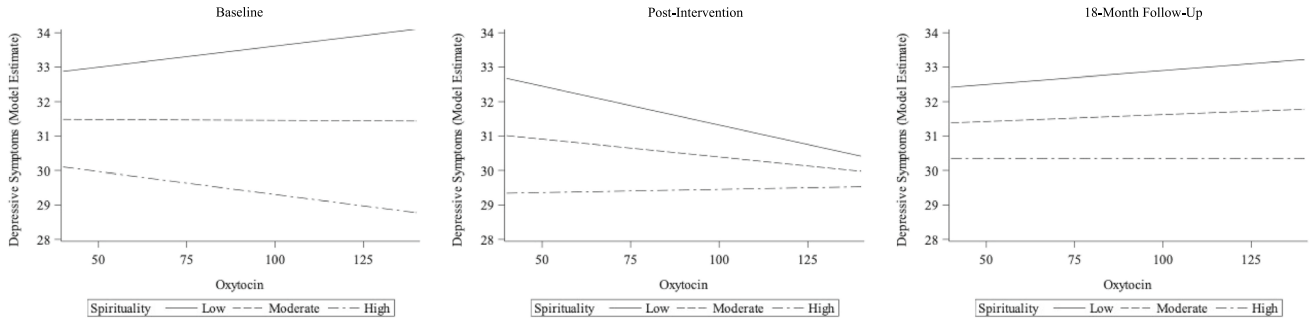


Fig. 3 The effect of oxytocin as a function of spirituality on depressive symptoms at baseline, post-intervention, and the 18-month follow-up

at baseline, $Z = 8.49$, $p < 0.01$, as well as linearly over time, $Z = 1.86$, $p = 0.03$. In the next model, spirituality had a significant simple negative effect on depressive symptoms, $t(1007) = -5.00$, $p < 0.01$. The interactions between spirituality and oxytocin, $t(1007) = 2.62$, $p < 0.01$, as well as spirituality, oxytocin, and linear time, $t(1007) = 2.75$, $p < 0.01$, were also significant (see Fig. 3). Individuals remained significantly different at baseline, $Z = 8.93$, $p < 0.01$, trended toward demonstrating different linear, $Z = 1.41$, $p = 0.08$, and quadratic trajectories, $Z = 1.44$, $p = 0.07$. Conditional models were better fitting than the unconditional model, $\Delta\chi^2$ *s* (9, 208) = 44.45–91.10, *ps* < 0.01 (see Table 1) due to resilience as well as spirituality and oxytocin over time contributing to the variance in depressive symptoms.

Discussion

The mental health benefits expected from meditation (Edwards & Loprinzi, 2018; Fredrickson et al., 2008) were not observed when examining all participants in aggregate specifically for depressive symptoms. Participants engaged in one of two kinds of meditation (loving-kindness and mindfulness) and mental health trajectories did not differ between interventions. Previous studies have found a reduction in depressive symptoms following meditation (Fredrickson et al., 2008), but that was specific to loving-kindness meditation. The present study also included mindful meditation. In one study, though mindfulness was related to lower depressive symptoms in adult populations, time spent in mindful meditation did not directly predict depressive symptoms similarly to the present study findings (Parmentier et al., 2019). Time spent meditating did relate to mindfulness, which in turn negatively associated with depressive symptoms (Parmentier et al., 2019). Participants in the present study did not demonstrate a similar pattern between meditation and mental health on average, but participants had significantly different baseline levels of mental health symptoms and they changed over the course of the study period in trajectories that were significantly differently from one another. This set directly up for testing individual differences in these mental health trajectories and assess for whom does meditation most improve mental health trajectories.

Two psychological resources (resilience and spirituality) and two biological resources (CVT and OT) were tested for their individual and interactive effects on positive and negative mental health symptom trajectories in midlife adults. It was hypothesized that individual differences in psychological resources (resilience and spirituality) and biological resources (CVT and OT) would moderate changes in positive (subjective well-being) and negative (depression) mental health following a meditation intervention in a positive and negative direction, respectively. Furthermore, it was hypothesized that interactions between resilience and CVT as well as spirituality and OT would have cumulative effects on the changes in mental health following a meditation intervention above and beyond that of each predictors' individual effect (synergy hypothesis). Findings provided some evidence regarding who may be most likely to experience short- and long-term mental health gains following a 6-week meditation intervention.

The most consistent present findings regarded resilience. Resilience has been associated with better mental health in adults (Mayordomo et al., 2016; Waugh & Koster, 2015). In line with that breadth of research, mid-life adults higher in resilience reported higher subjective well-being and lower depressive symptoms across the study period. Individual differences in resilience also predicted different mental health gains following meditation. It was hypothesized that greater resilience would act as a catalyst for mental health benefits, and data provided only delayed support for that prediction, at the 18-month follow-up. Individuals relatively low in resilience (one standard deviation below the mean) had the largest gains in subjective well-being symptoms from the meditation intervention. Their subjective well-being scores, however, decreased from immediately post-intervention to the 18-month follow-up and were only slightly higher than baseline at the 18-month follow-up. This difference was only marginally significant. These results suggest that for these individuals, the benefits gained were more short term

and not fully maintained. Moderate (at the sample mean) resilience participants also showed gains in subjective well-being following the meditation intervention and continued to increase minimally, though nonsignificant, from post-intervention to the 18-month follow-up. Moderately resilience participants' 18-month follow-up scores were higher than baseline, indicating that their small positive mental health gains were maintained. It can be cautiously concluded that higher levels of resilience may act as a catalyst for subjective well-being gains 18 months following meditation interventions. Those low in resilience also experienced the greatest depression decreases immediately from meditation, yet this improvement was not maintained by the 18-month follow-up. Relatively moderate and high resilience participants' depressive symptoms changed very little from learning to meditate. In sum, those who saw the greatest acute/short-term mental health benefits were low in resilience, whereas those who saw longer-term benefits were high in resilience.

Resilience was not the only intrapersonal characteristic predicting who received mental health benefits from meditation; there were similar effects for oxytocin (OT). Participants relatively low or moderate in OT significantly increased in subjective well-being following the meditation intervention whereas participants high in OT remained stable. All OT groups reported similar levels of subjective well-being from post-intervention to the 18-month follow-up, indicating that the positive mental health gains were maintained. In sum, OT did not act as a catalyst for subjective well-being gains but instead, those who were relatively low in OT benefited the most from the meditation intervention. One interpretation for this finding is that participants with high level of OT already report high levels of subjective well-being, which did not further improve following meditation. Participants low and moderate in OT, also lower in subjective well-being at baseline, had more room to grow. Although previous research (Van Cappellen et al., 2016a, b) had found that administering OT prior to being introduced to meditation increased the amount of positive emotions experienced felt while meditating—a key subjective well-being component—evidence of a comparable effect on mental health with naturally higher levels of circulating OT was absent in the present study. Oxytocin's effect on depressive symptoms was a function of spirituality and that relationship was also a function of time. Across all study timepoints, being low in spirituality was related with higher depressive symptoms. This finding is consistent with numerous previous studies showing an association between spirituality and subjective mental health (Koenig, 2012). Interestingly, OT buffered this relationship, but only directly following the meditation intervention. Indeed, the mix of high oxytocin and engaging in meditation practice appeared to be particularly useful for relatively low-spirituality participants, with this combination resembling their high-spirituality counterparts (at any level of OT). It should be noted again that this effect was only evident directly after the mediative intervention and was not maintained at the 18-month follow-up.

Other findings did not support the original hypotheses. Though spirituality was expected to have similar mental health boosting effects as resilience, the present study only found that spirituality was associated positively with subjective well-being symptoms and negatively with depressive symptoms regardless of study time point. Although this adds to the growing body of literature regarding spirituality and mental health symptoms (Kashdan & Nezlek, 2012; Piedmont, 1999; Van Cappellen et al., 2016a, b), it does not support the original hypothesis that higher spirituality would result in greater mental health gains from meditation. These results align with another study that failed to find that daily spiritual experiences moderated the reduction in depressive symptoms following a mindfulness-based meditation intervention (Greeson et al., 2015). Future research may still consider testing this hypothesis using different measures/facets of spirituality or even religiosity. For example, one study distinguished among different aspects of spirituality and found diverging associations with depression and life satisfaction in a sample of midlife ($n = 306$) adults (Lifshitz et al., 2019). Additionally, there were no synergistic effects between resilience and CVT, nor did CVT significantly relate to either mental health outcome across the study period as originally hypothesized. Therefore, research on individual differences in CVT predicting gains in positive emotions following meditation (Kok et al., 2013) could not be extended to gains in mental health in the present study. Overall, the null findings for the present study do not necessarily indicate that these constructs are inert in midlife, but rather that individuals' degrees of spirituality or CVT when engaging in 6 weeks of meditation may neither augment nor hinder the mental health benefits that may be achieved through meditation practice.

Model building in the present study revealed noteworthy random effects findings; as mentioned above, mid-life adults began the study with significantly different levels of mental health and also significantly differed from one another on their trajectories of change in mental health during and following the meditation interventions. Although research has concluded that meditation is generally beneficial, data provided only mild evidence of a general effect, averaged across all study participants. This makes random effects analytical techniques key to better understanding individual differences in intervention responsiveness. Differences in starting point and trajectories were detected by employing linear mixed effects models, which are the most appropriate for clustered data (Fitzmaurice et al., 2011). After adding the pertinent intrapersonal characteristics, subjective well-being trajectory random effects were no longer significant,

indicating that these predictor variables explained the variance in mental well-being trajectories (i.e., for whom this intervention worked better). Random effects that remain significant in conditional models indicate that variables outside of the present study likely impact how individuals differed at baseline as well as how they changed during and after a meditation intervention. This occurred for CVT and resilience on depressive symptoms as well as OT and spirituality on depressive and subjective well-being symptoms.

Limitations and Future Research

Despite the advantages to the employed empirical and analytic approaches, this work also has noteworthy limitations. The present investigation was structured differently than other meditation studies to date. It did not directly test *how* meditation can affect well-being by measuring the "active ingredients" of meditation, such as mindfulness, compassion, or acceptance. Rather, the present study focused on *who* would get the most out of these interventions. Future research may want to extend this work by investigating whether the *how* of meditation's effects on well-being also interact with individual differences in predicting greater gains. In addition, changes over time in mental health following a meditation intervention were investigated yet the present study did not have a no-meditation comparison group. This study was not originally designed to compare meditation to no meditation, but to investigate the effects of positive emotions on lifestyle change, where meditation was used as an intervention to increase said positive emotions. Although this design allowed testing the primary question regarding who gets the most benefits, it did not allow determining whether meditation as an intervention works better or as well as other interventions or no intervention (Goyal et al., 2014). It was not hypothesized that personal resources would amplify the mental health benefits of one meditation type compared to another and, therefore, hypotheses were tested across meditation types. However, future research may want to disentangle meditation types for theoretical reasons not overviewed here or when testing other resources.

Another limitation due to missing data within participants at some time points, OT, and CVT were averaged across the study period. This is less than ideal because personal resources may build up or erode over time. Further research in this area needs richer data to explore changes over time in these important biological variables. Additionally, subjective well-being was only collected at three time points, as opposed to quarterly (see Supplemental Fig. 1). This limited the granularity of subjective well-being changes following the meditation interventions.

In sum, the present study provided preliminary evidence that resilience shapes the trajectory of intervention responsiveness and does so at different time scales for those scoring relatively low versus high on resilience. Key to the present findings was the inclusion of the 18-month follow-up assessment, allowing for differentiating between short-term and maintained mental health gains. The findings reported here regarding resilience should be replicated by systematically enrolling participants at low, moderate, and high levels of resilience to receive meditation training. Such work could reveal whether interventions to boost resilience should precede meditation training to optimize mental health benefits.

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Author Contribution NBS: analyzed the data and wrote the manuscript. PVC: collaborated with the design and implementation of the study as well as the writing and editing of the final manuscript. BLF: provided funding, implemented the study, and collaborated with the writing and editing of the final manuscript. All authors approved the final version of the manuscript for submission.

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Data Availability The data and statistical programming are available at Open Science Framework: https://osf.io/d9qux/.

Declarations

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

Consent to Participate All study participants completed written informed consent following orientation to the study.

Conflict of Interest The authors declare no competing interests.

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