Mindfulness (2014) 5:249–258
DOI 10.1007/s12671-012-0172-8

ORIGINAL PAPER

Tracking Longitudinal Changes in Affect and Mindfulness Caused by Concentration and Loving-kindness Meditation with Hierarchical Linear Modeling

Christopher J. May · Jared R. Weyker · Stephanie K. Spengel · Lisa J. Finkler · Scott E. Hendrix

Published online: 25 November 2012

Abstract We compared the relative effects of 5 weeks of either concentration or loving-kindness meditation (CM, LKM) on mindfulness (including two subscales—presence and acceptance) and affect using a multiple baseline ABA design. Hierarchical linear modeling (HLM) indicated that 48–71 % of the total variance was attributable to individual differences. While meditating, CM practitioners experienced progressive increases in mindfulness and acceptance, while LKM practitioners exhibited increases in mindfulness, presence, and positive affect. When practitioners ceased meditation, those in the CM condition declined in mindfulness, acceptance, and positive affect throughout the cessation period. Individuals in the LKM group showed a progressive decrease in presence and a singular drop in negative affect immediately following meditation. There was a dissociation between acceptance and presence, with CM influencing the former and LKM the latter. Because mindfulness and positive affect did not decrease after the meditation period for the LKM group, these results suggest that LKM may induce more enduring changes in these variables. However, while meditation-specific HLMs indicated differences between meditation types, a combined HLM with both meditation conditions showed no group differences in the meditation or cessation phases of the study. More substantial were individual differences in response to meditation; these point to the necessity of using either large sample sizes in group means testing for meditation research or techniques permitting individual-based analysis such as HLM and single-subject designs.

Keywords Hierarchical linear modeling · Multilevel modeling · Individual differences · Mindfulness · Affect · Meditation

Introduction

One under examined and sometimes puzzling issue with regard to meditation practice is the relationship between practice time and observed effects. For example, Leppma (2011) found that loving-kindness meditation (LKM) significantly impacted emotional concern, personal distress, perspective taking, and fantasy proneness, but found no relationship between these variables and practice time, with the exception of perspective taking, which evidenced a moderate correlation (r=0.292). Similarly, Davidson et al. (2003) showed that a Mindfulness-Based Stress Reduction (MBSR) program both decreased negative affect and increased electroencephalographic potentials associated with positive affect, but found no correlation between these effects and the frequency or duration of practice time. In another MBSR study, Carmody and Baer (2008) reported positive correlations between practice time and two facets of mindfulness—acting with awareness and nonreactivity—as well as psychoticism, but no significant correlation with 14 other variables that were significantly impacted by the MBSR program. In a meta-analysis of 30 MBSR studies, Carmody and Baer (2009) found no correlation between either the number of MBSR classes and outcomes or assigned meditation minutes and outcomes. Carmody and Baer (2009) also analyzed several permutations of subsets of the 30 studies, never finding a significant correlation. Indeed, some correlations were negative.

This puzzling juxtaposition of significant effects with non-significant practice times suggests that there are substantial individual differences in responsiveness to meditation practice.

C. J. May (✉) · J. R. Weyker · S. K. Spengel · L. J. Finkler
Life Sciences Department, Carroll University,
100 N. East Ave.,
Waukesha, WI 53186, USA
e-mail: cmay@carrollu.edu

S. E. Hendrix
Department of History, Carroll University,
Waukesha, WI, USA

Using hierarchical linear modeling (HLM) to examine LKM, Fredrickson et al. (2008) found a significant random effect for time, meaning that rates of change in regressed variables significantly differed between individuals. Positive emotion steadily increased with LKM practice, effectively tripling by the seventh week. Increased positive emotion, in turn, increased mindfulness. Following up on these participants, Cohn and Fredrickson (2010) found that positive emotion remained higher in those that continued meditating and correlated significantly with meditation time (r=0.25). HLM is a powerful statistical technique for examining both individual change and group differences. HLM enables a form of growth curve modeling, which yields relatively detailed information about the nature of individual differences—particularly when compared to the more common pre–post experimental designs. Because substantial individual differences have significant implications for common group means tests like ANOVA, it is important that individual differences be earnestly explored in order to better characterize the efficacy of meditation.

We used HLM to explore the relative efficacy of LKM and concentration meditation (CM) in increasing mindfulness and positive affect, while decreasing negative affect. Both LKM and CM increase facets of mindfulness and affect. For example, May et al. (2011) found that LKM increased the observe and describe subscales of the Five Factor Mindfulness Questionnaire (Baer et al. 2006, 2008). Similarly, Fredrickson et al. (2008) documented LKM's positive influence on mindfulness using the Mindfulness Attention Awareness Scale (Brown and Ryan 2003). May et al. (2011) did not, however, find changes in positive or negative affect using the Positive Affect Negative Affect Schedule (PANAS; Watson et al. 1988), despite an average of 485 min of meditation per participant. In contrast, Hutcherson et al. (2008) found that LKM increased positive mood and decreased negative mood after a single session of LKM. Likewise, Carson et al. (2006) determined that LKM reduces psychological distress. While these discrepancies with May et al. (2011) may be attributable to the different measures of affect, mood, and emotion used, we are inclined to think that individual differences are the larger culprit. CM also increases mindfulness (though CM is rarely clearly distinguished from mindfulness meditation) as seen in MBSR (Carmody and Baer 2008) and the validation of mindfulness measures (e.g., Baer et al. 2006, 2008). As noted earlier, Davidson et al. (2003) also found that MBSR induced psychophysiological changes in negative and positive affect. While both CM and LKM have salutary effects on mindfulness and affect, comparative research using HLM is necessary to determine their relative efficacies and growth curves on the same measures. This will enable more informed proscriptive advice about the practice of meditation to achieve particular psychological outcomes. We expected to observe greater increases in positive affect and decreases in negative affect with LKM compared to CM because LKM is an emotion-focused practice. We did not have an a priori hypothesis regarding differences between meditation conditions on mindfulness.

Method

Participants

Participants (N=31) were drawn from a freshman-level course jointly taught by the first and fifth authors at a small Midwestern university. The experimental protocol was approved by the university's institutional review board, and participation was voluntary. Participants were randomly assigned to either a CM condition (n=15) or an LKM condition (n=16). There was not a significant difference in gender balance between conditions, where 73 % and 67 % of participants were female in the CM and LKM groups, respectively, $t(28)=-0.386$, p=0.702. One participant in the LKM group missed 40 % of the data collection periods and was eliminated from all analyses. A participant in the CM group was also eliminated because of concerns the individual was not conscientious in diligently completing their questionnaires (see participant 8 in Fig. 1).

Meditation Instruction

Participants in both conditions received instruction on their respective meditation from the first author, who has practiced multiple types of meditation for approximately 9 years, and has attended several retreats on CM and LKM. Both groups were guided through their meditation for approximately 20 min. Groups were first asked to sit up straight in their chairs, with their feet on the floor, and their eyes either closed or softly gazing (not staring) at a place a few feet in front of them. Both groups then started with a progressive body scan. Beginning with their feet, participants slowly brought their awareness up through their body, noting and releasing any tension. Concentration meditators were then asked to identify a sensation associated with their breathing, such as the rise and fall of their stomachs, the expansion and contraction of their chests, or the warmth and coolness of air passing through their nostrils. Participants were instructed to stay with that sensation for the duration of their meditation. They were then simply instructed to keep their attention on that sensation. They were told that this would likely be difficult, and when their minds inevitably wandered, to simply bring it back to the task at hand. The goal, they were told, was not to stop thinking, but rather to pay attention to an object for a sustained period of time. Participants were given two tools to help them if they were struggling to maintain focus. They could either count their breaths, silently

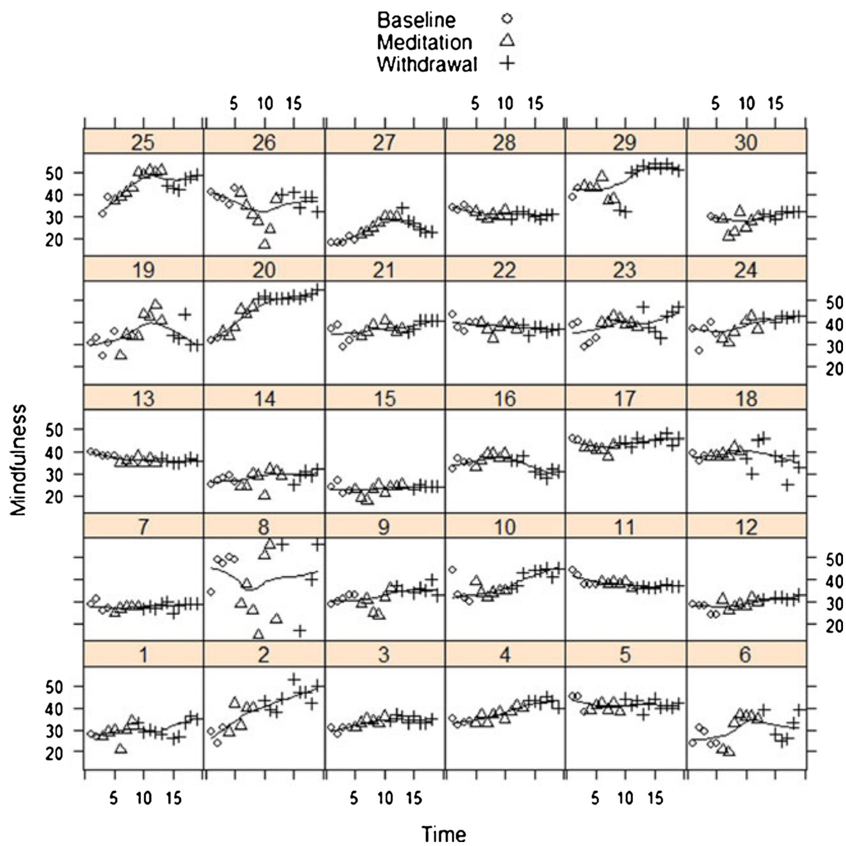


Fig. 1 Freiburg Mindfulness Inventory scores during baseline, meditation, and withdrawal periods for each participant. Lines represent moving averages

and repeatedly counting from 1 to 10, or they could silently say a word as they inhaled (such as "in") and as they exhaled (such as "out"). After the body scan, participants in the LKM group were asked to bring their awareness to their heart area, and imagine that as they inhaled, they inhaled into their heart, and as they exhaled, they exhaled from their heart. After several minutes, they were then asked to call to mind the image of someone who naturally evokes feelings of love and kindness. This might be a relative, a significant other, a good friend, or even a pet. They were then instructed to silently direct three phrases to that mental image: "May you be well," "May you be happy," and "May you be free from suffering." Participants were told that the important element was the genuine wish behind the words. If they forgot one or more of those three phrases, they could make up their own which carried the same intentionality. After several minutes, participants were then asked to change their mental image from someone who naturally evokes love and kindness to an image of themselves. They then directed the same three phrases to themselves, changing the pronoun: "May I be well," "May I be happy," and "May I be free from suffering." Finally, participants returned to imagining their breath emanating from their heart for a couple of minutes.

Design

We employed a multiple-baseline ABA withdrawal design. Participants in both conditions were tested at multiple time points before (A_1), during (B), and after (A_2) meditation practice. Multiple-baseline designs stagger the introduction of the intervention (B) to increase internal validity; causal inferences about the effects of an intervention are strengthened when the effects do not systematically overlap with extraneous temporal events (e.g., time-dependent stressors). Baseline duration ranged from 1 to 4 weeks. Participants then meditated for 5 weeks, and ceased meditating for 1–3 weeks. Participants also resumed meditation for 2 weeks following the withdrawal period (creating an ABAB design); however, multiple baselines were not used for this last period. Because every participant resumed meditating for the final 2 weeks of the semester, data were confounded with end of the semester stress, compromising internal validity. Therefore, we restricted our analysis to the ABA periods.

Measures

We measured mindfulness with the short form of the Freiburg Mindfulness Inventory (FMI; Walach et al. 2006). The short form consists of 14 items (α=0.86), such as "I see my mistakes and difficulties without judging them" and "I sense my body, whether eating, cooking, cleaning, or talking." Participants rated the frequency with which each statement was true in the last 3 days on a four-point scale. A total mindfulness score was calculated by summing each of the 14 item responses (some items were reverse scored).

Subsequent research to Walach et al. (2006) determined that there are two subscales within the 14-item FMI—a 4-item acceptance scale (α=0.71) and a 4-item presence scale (α=0.64; Kohls et al. 2009). Because the Cronbach alpha for presence falls below the 0.7 rule of thumb for acceptability, we interpreted presence results conservatively. The acceptance items were: "I am able to appreciate myself," "In difficult situations, I can pause without immediately reacting," "I am friendly to myself when things go wrong," and "I experience moments of inner peace and ease, even when things get hectic and stressful." The presence items were: "I am open to the experience of the present moment," "When I notice an absent mind, I gently return to the experience of the here and now," "I pay attention to what's behind my actions," and "I feel connected to my experience in the here-and-now."

Affect was measured using the PANAS (Watson et al. 1988). On a five-point scale, participants rated the extent to which they had felt 20 different affective states in the past few days. Ten of the 20 affective states were positive (e.g., "excited," "proud," α=0.88), and 10 were negative (e.g., "ashamed," "afraid," α=0.85). Positive and negative affect were calculated by summing the ten affective state ratings for each category.

Data Analysis

We analyzed data both qualitatively and quantitatively. Qualitatively, visual inspection of dependent-variable-by-time plots is common practice in single-subject designs like the current study. Plots were examined for evidence of shifts in level and/or slope from A-to-B and B-to-A transitions. We used the results from our qualitative analyses to guide the construction of appropriate statistical models.

Quantitatively, we examined hypotheses using hierarchical linear modeling (also known as multilevel modeling and mixed effects modeling). The level 1 regression equations for all of HLMs were segmented regression equations, enabling the comparison of level and slope differences between study periods. This represents a type of growth curve modeling.

HLM is a powerful method for analyzing correlated data (for a review, see Dedrick et al. 2009). When measures are obtained at multiple time points for a number of individuals, the residuals within a subject will be highly correlated relative to the residuals across subjects. Analyzing a data set without taking these correlated residuals into account would violate the assumption of most inferential statistics, which require that errors be independent. Correlated errors reduce the standard error, thereby inflating the probability of finding a significant effect and increasing the likelihood of a type I error. However, residuals within particular individuals should be uncorrelated (unless there is autocorrelation in a longer time series). Separating a regression analysis into two levels—time and individuals—avoids violating the assumption of independence. The two-level structure of the present investigation's HLMs partitioned the total variance into a component attributable to within-subjects effects (e.g., time) and a component resulting from individual differences.

HLM also allows for the straightforward inclusion of random effects. An effect is random if it can be thought of as drawn from a larger population. For example, the amount and interval of time points at which participants were tested represents just one possible sampling of time, and so time-related predictors may be considered random effects. In contrast, group is a fixed effect because there are only two options—participants are either in the CM or the LKM condition. Random effects imply that there are random variables, not included in the model, that influence the weight of an effect for a particular individual. To model a random effect, an error term representing individual differences for a particular regression coefficient is included. If there are not significant individual differences, this error term in left out, and the variable is treated as a fixed effect. Where there are significant individual differences for a variable, adding a random effects term facilitates a better estimate of that variable's regression coefficient. We assessed the significance of random effects in two ways. Qualitative analysis highlighted those variables that appeared to have meaningful individual differences. An HLM was then run with random error terms included for each of these variables. If the variance of a random effect was significant, the error term was retained. Otherwise, it was removed.

All HLMs included five predictors, as shown in the level 1 model below. TIME coded the relative time point a measurement was taken, ranging from 1 to 19. ISTART and ISTOP are dummy variables, coding for the time periods before (0) and after (1) starting and stopping meditation, respectively. SSTART and SSLOPE are also dummy variables, which coded the amount of time since a participant either began or finished meditation practice. In the level 1 model, TIME represents the baseline period before meditation practice, ISTART and ISTOP represent shifts in the level of a dependent variable between periods (A-to-B, B-to-A), and SSTART and SSTOP represent the slopes of changes during and after meditation. Because all of the independent variables at both levels had defined meanings when equal to zero, we did not mean-center or effect-code them.

Level 2 models took multiple forms. The primary model, hereafter called the combined model and shown below, included GROUP, which coded for CM condition (0) or the LKM condition (1). Random effect terms (u) were included as described above. We also examined HLMs for each condition alone (CM model and LKM model). Meditation-specific level 2 models included only intercepts and random effect terms.

The level 2 random effects marked in the following equation were significant for all models except for four: the CM model for acceptance (γ_5 was a fixed effect), the CM model for positive affect (γ_5 was a fixed effect), the LKM model for negative affect (γ_3 and γ_5 were fixed effects), and the LKM model for presence (γ_3 was a fixed effect).

Level 1 Model (Time)

$$y_{ti} = \beta_{0i} + \beta_{1i}(\mathrm{TIME_{ti}}) + \beta_{2i}(\mathrm{ISTART_{ti}}) + \beta_{3i}(\mathrm{SSTART_{ti}}) + \beta_{4i}(\mathrm{ISTOP_{ti}}) + \beta_{5i}(\mathrm{SSTOP_{ti}}) + r_{ti}$$

Level 2 Model (Individuals)

$$\beta_{0i} = \gamma_{00} + \gamma_{01}(\mathrm{GROUP_i}) + u_{0i}$$

$$\beta_{1i} = \gamma_{10} + \gamma_{11}(\mathrm{GROUP_i})$$

$$\beta_{2i} = \gamma_{20} + \gamma_{21}(\mathrm{GROUP_i})$$

$$\beta_{3i} = \gamma_{30} + \gamma_{31}(\mathrm{GROUP_i}) + u_{3i}$$

$$\beta_{4i} = \gamma_{40} + \gamma_{41}(\mathrm{GROUP_i})$$

$$\beta_{5i} = \gamma_{50} + \gamma_{51}(\mathrm{GROUP_i}) + u_{5i}$$

Outliers, defined as points greater than 1.5 times the interquartile range, were identified and removed for each individual on each dependent variable. Q-Q plots of level 1 residuals for each individual were also used to identify and eliminate singular outliers.

We assessed normality of the residuals at both levels. We tested level 1 residuals for each individual at level 2 using the Shapiro–Wilk (S–W) statistic. We also used the S–W test to examine the residuals of random effects at level 2. Finally, we verified multivariate normality by checking the linearity of the Mahalanobis distance residuals.

Analyses were conducted using HLM 7.0. All models converged using the restricted maximum likelihood estimation procedure.

Because we expected changes to occur in a specific direction between ABA transitions, these results were evaluated using one-tailed tests. Differences between CM and LKM groups were evaluated with two-tailed tests. All p values were derived using robust standard errors in HLM to protect against violations of homogeneity of variance.

Procedure

For each week of testing, participants filled out an FMI and PANAS survey twice a week, every Monday and Thursday. Surveys were administered at the beginning of a class period. During dates where class was not in session (e.g., Thanksgiving Thursday) or when students were absent from class, data were not collected. Data for skipped questions (which were infrequent) were replaced with the mean value for that question. Baseline testing was spread over a period of 4 weeks. Administration of the FMI and PANAS began in the first week. At the start of the second week, randomly selected participants began their assigned meditation practice. Two to three new participants per day (for the 5 days of the work week) would begin their practice. By the conclusion of the fourth week, all participants had begun to practice their meditation. All participants practiced their assigned meditation for 5 weeks, at which point they ceased meditating. Survey administration continued for 1–3 weeks. Participants were instructed to practice for 15 min per day on 3 days per week and record their meditation times in a log. Participants were informed of the importance of honest reporting. If they did not practice for the assigned amount of time, they were asked to indicate as such—there would be no penalty for lack of meditation practice. The average meditation time for concentration meditators was 212.93 min (SD=22.49), compared to 210.93 min (SD=25.38) for loving-kindness meditators.

Results

Qualitative Analyses

Figure 1 depicts the pattern of total FMI score over time for each participant. Meditation had a discernible effect for some participants, but not for others. For example, participant 27 exhibited a clear rise in FMI during meditation, followed by a decline during the withdrawal phase. Others, like participant 7, exhibited little change in mindfulness across the study period. Additional patterns are also apparent. Participant 20's FMI scores increased during meditation and leveled off, rather than decreasing, during the withdrawal period. This indicates that the effects of meditation may not always reverse immediately. Still others, like participant 26, became *less* mindful during the meditation period, only increasing during the withdrawal period. Participant 16 did not show an increase during meditation, but did exhibit a marked decrease following meditation. In short, there were substantial individual differences in the slopes of change between phases of the study. Some showed no observable changes, while others, like participants 25 and 27, exhibited clear increases in mindfulness as a result of meditation, though scores ascended at different rates.

Also notable are dynamics that do not appear. For example, there were not dramatic shifts in the levels of mindfulness at the phase transitions. While mindfulness may have increased across the meditation period for a participant, that increase was generally continuous rather than discontinuous with the baseline period. The absence of discontinuity between study phases suggests that results cannot be attributed to a demand effect. The fairly linear slopes and lack of discontinuities also make intuitive sense—meditation takes time to exert its effects and are cumulative, at least at the beginning stages of practice. These results further indicate that the slopes of change from baseline to the meditation period and from the meditation period to the withdrawal period should be modeled as random effects in a HLM, whereas levels (intercepts) may be modeled as fixed effects. A similar variety of dynamics were evident for each of the other variables as well.

Quantitative Analyses

To determine the relative amount of variance that each level of our HLMs could explain, we calculated the intraclass correlation coefficients (ICCs) for each dependent variable. ICCs were computed by dividing the level 2 variance (u) of an unconditional model by the sum of u and the level 1 variance (r):

Level 1 Unconditional (Intercept-Only) Model

$$y_{ti} = \beta_{0i} + r_{ti}$$

Level 2 Unconditional (Intercept-Only) Model

$$\beta_{0i} = \gamma_{00} + u_{0i}$$

The ICC for FMI was 0.71, indicating that 71 % of the total variance of the unconditional model is attributable to differences between individuals, whereas 29 % represents variation between time points within individuals. The ICCs for presence, acceptance, and positive affect were similarly high at 0.66, 0.62, and 0.62, respectively. Negative affect registered the lowest ICC of 0.48, signifying slightly greater variance across time than between participants. These ICC values reflect the variability across time and between individuals apparent in Fig. 1.

For illustrative purposes, we will step through the analysis of FMI scores in detail, and present the remaining results in shorter form. Table 1 lists the regression coefficients and associated statistics for FMI scores. Plugging these coefficients into the combined model yields the following two equations for CM and LKM, respectively:

$$FMI_{CM} = 32.92 - 0.66(TIME) - 0.45(ISTART) + 1.32(SSTART) - 0.02(ISTOP) - 0.47(SSTOP)$$

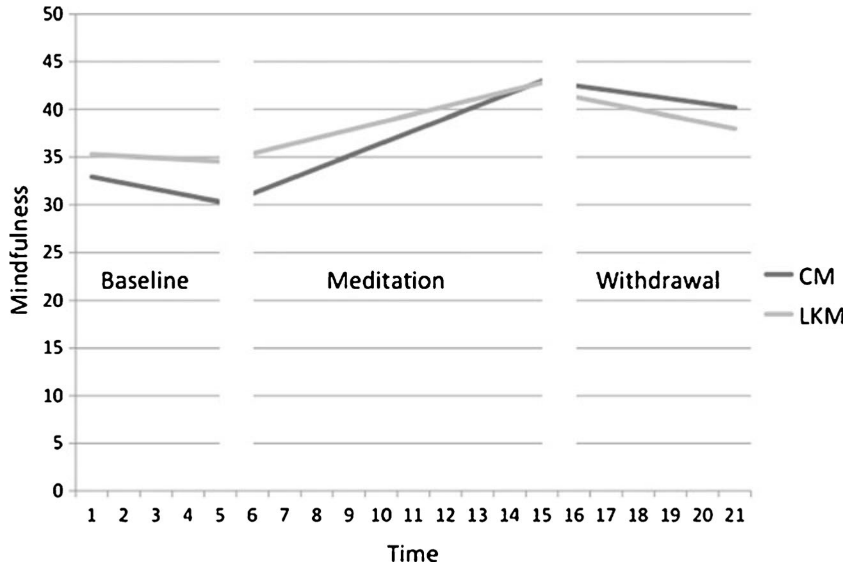
Table 1 Combined hierarchical linear model for total Freiburg Mindfulness Inventory scores

	γ (SE)	*t* ratio	*df*	*p* value
For INTRCPT1, β_0				
INTRCPT2, γ_{00}	32.92 (1.78)	18.48	27	<0.001
GROUP, γ_{01}	2.35 (2.47)	0.95	27	0.35
For TIME, β_1				
INTRCPT2, γ_{10}	−0.66 (0.32)	−2.03	420	0.043
GROUP, γ_{11}	0.48 (0.41)	1.19	420	0.236
For ISTART, β_2				
INTRCPT2, γ_{20}	−0.45 (0.99)	−0.45	420	0.654
GROUP, γ_{21}	0.42 (1.55)	0.27	420	0.785
For SSTART, β_3				
INTRCPT2, γ_{30}	1.32 (0.34)	3.91	27	<0.001
GROUP, γ_{31}	−0.49 (0.44)	−1.1	27	0.282
For ISTOP, β_4				
INTRCPT2, γ_{40}	−0.23 (0.80)	−0.29	420	0.775
GROUP, γ_{41}	−0.59 (1.51)	−0.4	420	0.693
For SSTOP, β_5				
INTRCPT2, γ_{50}	−0.47 (0.25)	−1.89	27	0.069
GROUP, γ_{51}	−0.2 (0.53)	−0.38	27	0.71

$$FMI_{LKM} = 35.27 - 0.18(TIME) - 0.03(ISTART) + 0.83(SSTART) - 0.82(ISTOP) - 0.67(SSTOP)$$

These equations are plotted in Fig. 2. There was not a significant difference between meditation groups in y-intercepts (p=0.35). The baseline slope was negative for both CM (−0.66) and LKM (−0.66+0.48). Baseline slope was significant for CM, $t(420)=-2.03$, p=0.04, and there was not a significant difference between groups. However, in examining the meditation-specific models, baseline slope was significant for CM (b=−0.66, SE=0.32, t=−2.07, df=208, p=0.04), but not for LKM. The reason for a significant decrease in mindfulness scores over the baseline period for concentration meditators is unclear. At the beginning of the meditation period, FMI dropped an insignificant 0.45, while LKM fell by a negligible 0.03. For each time point subsequently, FMI rose by 1.32 (SE=0.34) and 0.83 (SE=0.44) for CM and LKM, respectively. The rise in FMI scores during the meditation period was significant for the CM group, $t(27)=3.91$, $p<0.001$, one-tailed, and the slope for the LKM group was not significantly different from the CM slope. To determine if the LKM slope represented a significant increase, we examined the LKM model, which determined that LKM slope did increase significantly, b=0.88, SE=0.28, $t(14)=3.15$, p=0.004, one-tailed. When participants stopped meditation practice, FMI scores dropped insignificantly for both the CM (−0.23) and LKM groups (−0.82). The latter insignificant result was confirmed with the LKM

Fig. 2 Segmented regressions on Freiburg Mindfulness Inventory scores for participants in the concentration meditation (CM) and loving-kindness meditation (LKM) conditions



model. Finally, FMI scores continued to fall at a rate of 0.47 (*SE*=0.25) per measurement time for the CM group, $t(27)=-1.89$, $p=0.04$, one-tailed and 0.67 (SE=0.53) per time point for the LKM condition. While the slope for LKM was not significantly different from the CM slope, the LKM model indicated the decrease in slope from the meditation period was not significant.

To summarize, concentration meditators' FMI scores significantly increased across the meditation period, and significantly decreased across the post-meditation period. Loving-kindness meditators also had a significant increase in FMI across the meditation period, but did not have a significant decrease following meditation. With the exception of the minor difference between conditions in the rate of descent post-meditation (which was determined by comparing models—the difference in the combined HLM model was not significant), there were few differences between groups. Indeed, the R^2 for the group variable was 0.01.

We then examined the two subscales of the FMI—presence and acceptance. For presence, there were no significant effects in the combined model or the CM model. In the LKM model, the intercept when participants stopped meditating (β_{40}) was turned into a random effect ($p=0.01$) so that all residuals were normally distributed. In addition, β_{30} was a fixed effect rather than random effect since its variance was not significant. The slope when meditating was significant, $t(218)=3.51$, $p<0.001$, one-tailed, increasing 0.46 (SE=0.13) with each time point (see Table 2). That this significant slope was modeled as a fixed rather than random effect suggests that LKM is particularly efficacious in increasing presence across individuals. The slope following the cessation of meditation was also significant, $t(14)=-2.2$, $p=0.02$, one-tailed, decreasing by 0.36 (SE=0.17) with each time point. For acceptance, the combined model indicated that four participants (two in each condition) did not have normally distributed residuals. We ran models both with and without these four participants and found the same pattern of significance. We report the statistics for the combined model with all participants included. Baseline slope was significantly negative for the CM group, $b=-0.25$, SE=0.12, $t(425)=-2.18$, $p=0.03$. The LKM group had a significantly different baseline slope, $b=0.07$, SE=0.16, $t(425)=2.03$, $p=0.04$, which the LKM model indicated did not represent a significant change. The reason for the negative baseline slope for the CM group is unclear. There was a significant positive slope for the CM group during the meditation period, $b=0.55$, SE=0.1, $t(27)=5.48$, $p<0.001$, one-tailed. The meditation period slope for the LKM group was significantly different from the CM group, $b=-0.43$, SE=0.18, $t(27)=-2.34$, $p=0.03$, and did not represent a significant increase over the baseline period according to the LKM model. Finally, there was a negative slope for the CM group following the meditation period, $b=-0.21$, SE=0.08, $t(27)=-2.44$, $p=0.01$, one-tailed. While the LKM group did not significantly differ from this, the LKM model indicated that this slope was only marginally significant ($b=-0.23$, SE=0.13, $t=-1.7$, $df=14$, $p=0.054$, one-tailed).

In summary, LKM caused an increase in presence during meditation, which progressively decreased during the post-meditation period. In contrast, CM caused an increase in acceptance throughout the meditation period, which fell during the post-meditation period. These results indicate a dissociation between LKM and CM—namely that LKM has a greater influence on presence, while CM has a greater influence on acceptance.

Figure 3 plots the segmented regression equations for positive and negative affect. With respect to positive affect, the combined model showed that those in the LKM condition started the study with higher positive affect, $b=5.22$, SE=2.48,

Table 2 Significance of regression coefficients for concentration meditation (CM) and loving-kindness meditation (LKM) models

Scale	CM			LKM		
	γ_{10}	γ_{30}	γ_{50}	γ_{30}	γ_{40}	γ_{50}
Mindfulness	0.039	<0.001	0.045	0.004	n.s.	n.s.
Presence	n.s.	n.s.	n.s.	<0.001	n.s.	0.023
Acceptance	0.03	<0.001	0.01	n.s.	n.s.	0.054
Positive affect	n.s.	n.s.	0.01	0.044	n.s.	n.s.
Negative affect	n.s.	n.s.	n.s.	n.s.	0.026	n.s.

Coefficients that were not significant for any dependent variable on a particular model have been omitted. γ_3 and γ_5 p values were derived using one-tailed tests, while γ_1 and γ_4 p values were derived using two-tailed tests (see text for explanation)

$t(27)=2.1$, $p=0.045$. There were no changes in positive affect when beginning meditation; however, the LKM model revealed a significant positive slope during the meditation period, $b=0.86$, SE=0.47, $t(14)=1.84$, $p=0.04$, one-tailed (see Table 2). The CM group had a significant negative slope during the post-meditation period, $b=-0.7$, SE=0.3, $t(27)=-2.38$, $p=0.01$, one-tailed. While the LKM group did not significantly differ from the CM group, the LKM model did not reveal a significant decrease in positive affect during the post-meditation period. With regard to negative affect, there were no significant differences between conditions or between time periods according to the combined model. However, the LKM model revealed a significant decrease in negative affect immediately upon the cessation of meditation, $b=-3.67$, SE= 1.63, $t(234)=-2.24$, $p=0.01$, one-tailed. The reason for this sudden drop in negative affect is unclear—perhaps participants in the LKM group felt relief to have finished the meditation period. In summary, the CM group decreased in positive affect after concluding meditation, while the LKM group increased in positive affect during the meditation period. In addition, the LKM group experienced a sudden decline in negative affect when they finished meditating.

Discussion

Concentration meditators experienced progressive increases in general mindfulness and acceptance while meditating. When they ceased meditation, their levels of mindfulness, acceptance, and positive affect increasingly fell. Loving-kindness meditators experienced progressive increases in mindfulness, presence, and positive affect while meditating, a progressive decrease in presence following meditation, and a singular drop in negative affect immediately following meditation. On the proposition that any significant changes between phases of the study warrants rejection of the null hypothesis, we conclude that concentration meditation significantly affected mindfulness, acceptance, and positive affect, while loving-kindness meditation significantly impacted mindfulness, presence, positive affect, and negative affect.

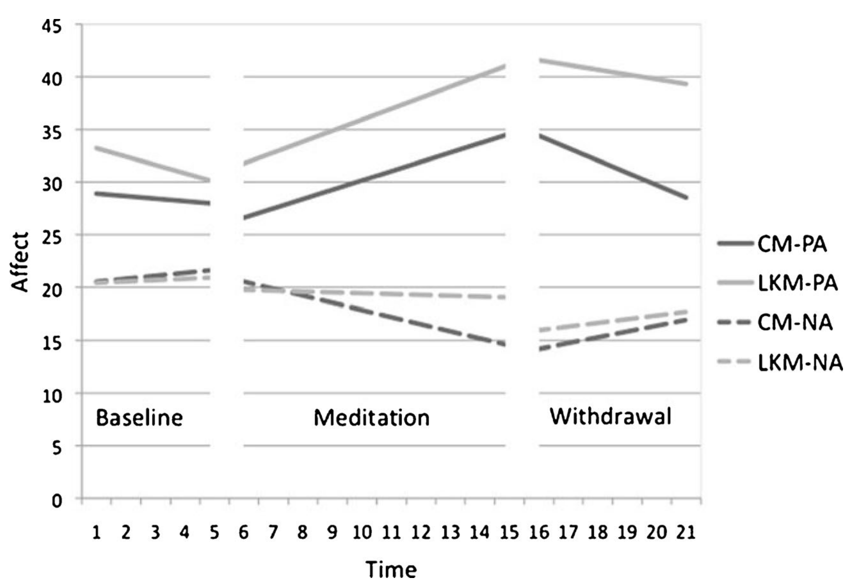


Fig. 3 Segmented regressions on positive affect (PA) and negative affect (NA) for participants in the concentration meditation (CM) and loving-kindness meditation (LKM) conditions

The different effects of concentration and loving-kindness meditation can only be inferred indirectly, however, by comparing results from the meditation-specific models; there were no differences during and after the meditation period between conditions when directly tested in the combined model.

These results partially supported our initial hypotheses. For all variables, we expected significant changes from baseline to meditation and from meditation to the withdrawal period. This held only for mindfulness and acceptance in the CM group and for presence in the LKM practitioners. Other variables changed during one phase transition, but not another. Unlike CM practitioners, participants in the LKM group did not experience a progressive decline in mindfulness following meditation. In addition, those in the LKM group had increases in positive affect while meditating, which did not decrease during the withdrawal phase. These results suggest that LKM may induce more enduring changes in mindfulness and positive affect than CM. Further research is needed to test these hypotheses.

These results also point toward a dissociation between LKM and CM in their positive effects on presence and acceptance, respectively. This is a somewhat surprising pattern. For example, one of the items in presence is, “When I notice an absent mind, I gently return to the experience of the here and now,” which is very similar to a portion of the instructions given for CM, but not LKM. However, another presence item, “I am open to the experience of the present moment” may be similar to an item in the “describe” subscale of the Five Factor Mindfulness Questionnaire (FFMQ; Baer et al. 2006, 2008), “I pay attention to sensations such as the wind in my hair or the sun on my face.” LKM does significantly increase scores on this subscale (May et al. 2011). In addition, LKM might be thought, a priori, to exert a bigger effect on acceptance since scores on the item, “I am friendly to myself when things go wrong,” would rise with the practice of wishing oneself well. Nonetheless, other items in the acceptance subscale may be more strongly associated with CM. For example, the acceptance item, “In difficult situations, I can pause without immediately reacting” is the same as an item from the non-judging subscale of the FFMQ. While CM (or a CM-like practice) has been associated with non-reactivity (Baer et al. 2006, 2008), LKM has not been (May et al. 2011). Finally, the acceptance item, “I am able to appreciate myself,” may fit into the non-judging dimension of the FFMQ, which LKM has also not been shown to increase (May et al. 2011). These results point toward the importance of comparative research using comprehensive and psychometrically sound assessment measures for understanding both the absolute and relative effects of different types of meditation. Future research can further test the robustness of the dissociation between presence and acceptance with respect to LKM and CM. This research would have clear clinical implications since both presence and acceptance are important components of multiple therapies, such as Mindfulness-Based Cognitive Therapy and Acceptance and Commitment Therapy.

We also expected that the LKM group would score higher on positive affect and lower on negative affect during the meditation period compared to the CM group since LKM is an emotion-focused practice. The LKM HLM indicated a rise in positive affect during meditation, which was sustained during the withdrawal period; however, there was not a difference with CM in the combined HLM. Similarly, there were no group differences in negative affect.

Perhaps most importantly, we found significant individual differences in response to meditation. This was clearly visible in Fig. 1, and reflected in both intraclass correlation coefficients of 0.48–0.71 and numerous significant random effects. These substantial individual differences suggest that typical group analyses of the effects of meditation may be suboptimal, at least until mediating/moderating variables are identified. Some initial research in this direction has been done, highlighting the role of tendencies to ruminate (Barnhofer et al. 2010). HLM has the advantage of appropriately accommodating and analyzing both intra- and inter-individual differences. Other examples of meditation research using HLM include Carson et al. (2006), Fredrickson et al. (2008), Jain et al. (2007), Kumar et al. (2008), and Short et al. (2010).

One limitation of the current research was the relatively limited number of time points for each phase of the study. This constrained our regression analyses to linear trends. More time points would enable an examination of non-linear growth patterns to better characterize individual differences.

A second limitation was the sample size. With 14–15 participants per meditation condition, the current investigation had only sufficient power to detect differences between groups involving large effect sizes (see Cohen 1992). Larger groups would be necessary to identify smaller effects. However, as we noted above, substantial individual differences in meditation responsiveness pose challenges for meditation research, particularly in environments or under conditions where large samples are less feasible to collect. In addition to HLM, an alternative approach for investigating the relative effects of multiple meditation types would be to examine within-individual, rather than between-individual, changes. For example, in an alternating treatment single-subject design, participants could toggle repeatedly between the practice of CM and LKM.

Further research will enable researchers and clinicians to better understand individual differences with respect to meditation—both in terms of whether and how much individuals respond to different types of meditation, and in isolating the comparative effects of different meditation practices. This, in turn, will enhance proscriptive advice about meditation practice. In individuals for whom meditation is contraindicated (see Dobkin et al. 2012), clinicians may recommend more beneficial interventions. For those who stand to benefit from the numerous salutary effects of concentration and loving-kindness meditations, clinicians may individually tailor a meditation regimen to maximize their health and well-being.

References

Baer, R. A., Smith, G. T., Hopkins, J., Krietemeyer, J., & Toney, L. (2006). Using self-report assessment methods to explore facets of mindfulness. *Assessment, 13*, 27–45.

Baer, R., Smith, G. T., Lykins, E., Button, D., Krietemeyer, J., Sauer, S., Walsh, E., Duggan, D., & Willams, J. M. G. (2008). Construct validity of the five facet mindfulness questionnaire in meditating and non-meditating samples. *Assessment, 15*(2), 329–342.

Barnhofer, T., Chittka, T., Nightingale, H., Visser, C., & Crane, C. (2010). State effects of two forms of meditation on prefrontal EEG asymmetry in previously depressed individuals. *Mindfulness, 1*(1), 21–27. doi:10.1007/s12671-010-0004-7.

Brown, K. W., & Ryan, R. M. (2003). The benefits of being present: mindfulness and its role in psychological well-being. *Journal of Personality and Social Psychology, 84*, 822–848.

Carmody, J., & Baer, R. A. (2008). Relationships between mindfulness practice and levels of mindfulness, medical and psychological symptoms and well-being in a mindfulness-based stress reduction program. *Journal of Behavioral Medicine, 31*, 23–33. doi:10.1007/s10865-007-9130-7.

Carmody, J., & Baer, R. A. (2009). How long does a mindfulness-based stress reduction program need to be? A review of class contact hours and effect sizes for psychological distress. *Journal of Clinical Psychology, 65*(6), 627–638. doi:10.1002/jclp.20555.

Carson, J. W., Keefe, F. J., Lynch, T. R., Carson, K. M., Goli, V., Fras, A. M., et al. (2006). Loving-kindness meditation for chronic low back pain. *Journal of Holistic Nursing, 23*(3), 287–304. doi:10.1177/0898010105277651.

Cohen, J. (1992). A power primer. *Psychological Bulletin, 112*(1), 155–159.

Cohn, M. A., & Fredrickson, B. L. (2010). In search of durable positive psychology interventions: predictors and consequences of long-term behavior change. *Journal of Positive Psychology, 5*(5), 355–366.

Davidson, R. J., Kabat-Zinn, J., Schumacher, J., Rosenkranz, M., Muller, D., Santorelli, S. F., Urbanowski, F., Harrington, A., Bonus, K., & Sheridan, J. F. (2003). Alteration in brain and immune function produced by mindfulness meditation. *Psychosomatic Medicine, 65*, 564–570.

Dedrick, R. F., Ferron, J. M., Hess, M. R., Hogarty, K. Y., Kromrey, J. D., Lang, T. R., Niles, J. D., & Lee, R. S. (2009). Multilevel modeling: a review of methodological issues and applications. *Review of Educational Research, 79*(1), 69–102.

Dobkin, P. L., Irving, J. A., & Amar, S. (2012). For whom may participation in a mindfulness-based stress reduction program be contraindicated? *Mindfulness, 3*(1), 44–50. doi:10.1007/s12671-011-0079-9.

Fredrickson, B. L., Cohn, M. A., Coffey, K. A., Pek, J., & Finkel, S. M. (2008). Open hearts build lives: positive emotions, induced through loving-kindness meditation, build consequential personal resources. *Journal of Personality and Social Psychology, 95*(5), 1045–1062. doi:10.1037/a0013262.

Hutcherson, C. A., Seppala, E. M., & Gross, J. J. (2008). Loving-kindness meditation increases social connectedness. *Emotion, 8*(5), 720–724. doi:10.1037/a0013237.

Jain, S., Shapiro, S. L., Swanick, S., Roesch, S. C., Mills, P. J., Bell, I., & Schwartz, G. E. R. (2007). A randomized controlled trial of mindfulness meditation versus relaxation training: effects on distress, positive states of mind, rumination, and distraction. *Annals of Behavioral Medicine, 33*(1), 11–21. doi:10.1207/215324796abm3301_2.

Kohls, N., Sauer, S., & Walach, H. (2009). Facets of mindfulness—results of an online study investigating the Freiburg mindfulness inventory. *Personality and Individual Differences, 46*(2), 224–230.

Kumar, S., Feldman, G., & Hayes, A. (2008). Changes in mindfulness and emotion regulation in an exposure-based cognitive therapy for depression. *Cognitive Therapy and Research, 32*(6), 734–744. doi:10.1007/s10608-008-9190-1.

Leppma, M. (2011). The effect of loving-kindness meditation on empathy, perceived social support, and problem-solving appraisal in counseling students. Dissertation, University of Central Florida.

May, C. J., Burgard, M., Mena, M., Abbasi, I., Bernhardt, N., Clemens, S., Curtis, E., Daggett, E., Hauch, J., Housh, K., Janz, A., Lindstrum, A., Luttropp, K., & Williamson, R. (2011). Short-term practice of loving-kindness meditation produces a state, but not a trait, alteration of attention. *Mindfulness, 2*(3), 143–153. doi:10.1007/s12671-011-0053-6.

Short, E. B., Kose, S., Mu, Q., Borckardt, J., Newberg, A., George, M. S., & Kozel, F. A. (2010). Regional brain activation during meditation shows time and practice effects: an exploratory fMRI study. *Evidence-Based Complementary and Alternative Medicine, 7*(1), 121–127.

Walach, H., Buchheld, N., Buttenmuller, V., Kleinknecht, N., & Schmidt, S. (2006). Measuring mindfulness—the Freiburg mindfulness inventory (FMI). *Personality and Individual Differences, 40*, 1543–1555.

Watson, D., Clark, L. A., & Tellegen, A. U. (1988). Development and validation of brief measures of positive and negative affect: the PANAS scales. *Journal of Personality and Social Psychology, 54*(6), 1063–1070.