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Intra-individual study of mindfulness: ecological momentary perspective in post-surgical lung cancer patients

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Abstract The period of recovery following a lung-cancer surgery presents unique challenges and psychological demands. The study utilized ecological momentary assessments (EMA) to repeatedly sample mindfulness states in a sample of mindfulness-untrained individuals following hospital discharge. Intra- and inter- individual variability was assessed to examine cancer patients' natural capacity to exhibit mindfulness states during two weeks of recovery. Fifty nine stage I lung cancer patients (61% women, mean age = 66.1, SD = 7.9) completed EMA twice a day for two weeks. Mean level of mindfulness in the sample was low and equaled .49 (SD = .51) on the 5 point scale, with older participants being less likely to endorse mindful states. Net variability in mindfulness, defined as the person-based standard deviation in momentary scores, equaled .42 (SD = .26), ranging for 0 to 1.3 and indicating very modest variability for most participants. Results of the multi-level variance partitioning model revealed 41.4% of variance in mindfulness scores at the inter-individual, 2.4% on the temporal (i.e., .2% weekly and 2.2% daily), and 56.2% on the momentary levels. Findings indicate that, for cancer patients recovering from surgery, the innate ability to exhibit mindfulness is limited. From the methodological standpoint, consideration of intra-individual variability has implications for conceptualization and design of EMA studies.

Keywords Mindfulness · Ecological momentary assessment · Intra-individual variability · Within-person dynamics · Lung cancer patients

Introduction

> There are so many ways to feel dissatisfied:
> So many different needs to meet, so many goals to keep striving towards …
> So much of the past you wish you could change, so many fears about the future…
> How could you ever be happy?
> … But then – the shock of an illness or an accident…
> And you can see the narrow ledge you're walking –
> The one you've always been walking – between life and death.
> And now it's all so simple and makes perfect sense –
> Life is temporary and fragile, precious beyond measure,
> And life contains nothing except this present moment
> This beautiful bright river of experience…
> Everything obliterated but the glory of this moment and the grandeur of the world itself.
> And you know that this is all there is, that this is where fulfillment lies
> And everything else is only a shadow play of the mind.

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The ancient Pali term "*sati,*" translated as mindfulness, refers to the state of being, characterized by flowing, relaxed and soft-focused awareness (Gunaratana, 1996). This concept is outside of the symbolic language of thought or word. The growing empirical interest in the topic of mindfulness is a result of accumulating evidence in applied domains of human functioning, including mental and physical health and interpersonal well-being, among others (e.g., Bohlmeijer et al., 2010; Brown, Ryan, & Cresswell, 2007; Chiesa & Serretti, 2009; Edenfield & Saeed, 2012). While mindfulness can be developed and enhanced through practice (Davidson et al., 2003; Shapiro et al., 2008), individuals appear to be inherently mindful to a certain degree (Baer, 2011; Brown & Ryan, 2003; Brown et al., 2007, Sauer et al., 2013), albeit their awareness is typically obstructed by habitual thinking. Goldstein (2002) refers to this innate quality as "unfabricated mindfulness." Studies with healthy populations without a formal training demonstrate that individuals vary in the degree to which they reveal and apply mindfulness in day-to-day living, which has an impact on general well-being and mental health (e.g., Brown & Ryan, 2003).

The primary aim of the current study was to investigate the extent of *unfabricated mindfulness* in situ in a group of lung cancer patients recovering from a surgical treatment. The methodology of ecological momentary assessments (EMAs; Shiffman et al., 2008; Smyth & Stone, 2003; Trull & Ebner-Priemer, 2009) was used to prompt repeated self-reports of inner states in the context of daily life in the two-week period of recovering following a surgery. Cancer patients, in particular, are a group affected by heightened psychological demands, anxiety, depression, and a general psychological distress (Maliski et al., 2003; Patz et al., 2000; van't Spijker et al., 1997). Thus, capturing the extent to which a predisposition towards mindfulness manifests in this population in applied, high-demand settings is informative and practical. The secondary aim of the study was to capitalize on the EMA methodology yielding rich repeated assessments and investigate the within-person dynamics and fluctuations in mindfulness states. The degree of these fluctuations could be telling of the ability to access mindfulness in situ. In the following sections, we review relevant research, present methodological details of the study, summarize results, and discuss implications for the field.

Lung cancer and mindfulness

The five-year survival rate for lung-cancer patients is estimated at 17.8%, which is lower compared to other types of cancer (American Lung Association, 2016). The prognosis is more optimistic for those with localized tumors eligible for surgical treatment. For cancer patients, in general, the period encompassing diagnosis, surgical treatment, and recovery is characterized by burdensome physical symptoms, impairment in functioning (Handy et al., 2002), and heightened psychological demands typically manifesting in significant psychological distress (Maliski et al., 2003). Due to elevated uncertainty about health and life prognosis, many patients report being emotionally overwhelmed with anxiety, depression, and a general psychological distress (Patz et al., 2000; van't Spijker et al., 1997).

Given heightened psychological demands of this transitional period, increased efforts have been put forward to design and implement mindfulness-based interventions tailored specifically to cancer patients (for review, see Ledesma & Kumano, 2009; Piet et al., 2012; Smith et al., 2005). Results demonstrate a reduction in symptoms of anxiety and depression (Ledesma & Kumano, 2009) and improvement in patients' adjustment to several types of cancer (Carlson et al., 2007; Cramer et al., 2012; Piet et al., 2012), including lung cancer (Schellekens et al., 2014). Significant improvements have been noted in mood disturbances (Birnie et al., 2010) and psychological and physiological symptoms of stress (Birnie et al., 2010; Tamagawa et al., 2013). Effect sizes appear to be medium (Piet et al., 2012), and further investigations are warranted to establish a more direct link between mindfulness skills and health outcomes. To our knowledge, there are limited empirical data on naturally occurring levels of mindfulness and its momentary fluctuations during the sensitive and demanding period of recovery following a cancer surgery. Such an investigation can uncover the extent of inherent propensity towards mindfulness. To our knowledge, this is the first study to investigate unfabricated mindfulness as it applies to daily life in recovering lung-cancer patients.

Ecological momentary assessments and mindfulness

The methodology of Ecological Momentary Assessment (EMA) is uniquely suitable for studying daily experiences and involves repeated sampling of internal states proximally to time and place of their occurrence. Questions are usually presented on portable devices (e.g., mobile phones) and focus on experiences in a particular moment in time ("right now", "in the last hour"). EMA methodology has been shown to enhance measurement accuracy and ecological validity, reduce recall and desirability biases, and capture fluctuations as they occur across time (Shiffman, 2009; Shiffman et al., 2008; Smyth & Stone, 2003; Ebner-Priemer & Trull, 2009a). Further, EMA maximizes ecological validity and generalizability to real-life applications, since assessments are taken in real-life circumstances

rather than in laboratory settings (Stone & Shiffman, 1994).

The feasibility of EMA methodology has been successfully established (Larson & Csikszentmihalyi, 1983; Wenze & Miller, 2010). Nonetheless, applications of EMAs in the field of mindfulness have been limited, although the method is conceptually well suited to the study of psychological states and processes. The important condition for EMAs is that a process under the investigation fluctuates over time to justify repeated sampling (Shiyko & Ram, 2011). While none of the studies have explicitly examined the degree of variability in mindfulness, they have captured these momentary states and used them for prediction of momentary well-being in untrained healthy college students (Brown & Ryan, 2003; Weinstein et al., 2009) and positive and negative affect in participants in a mindfulness-based stress reduction (MBSR; Kabat-Zinn, 2003) training (Gotink et al., 2016; Snippe et al., 2015). Thus, variability in momentary states appears to be inherent, although its extent is unknown. Importantly, there is a distinction between the global trait and momentary states of mindfulness. Moore and colleagues (2016) indicated that state mindfulness captured with EMA, along with other constructs (i.e., anxiety, depression), was sensitive to changes following the MBSR training, while the trait mindfulness was not. Similar findings have been reported by Ruscio et al. (2016) in a study of a brief self-initiated mindfulness meditation intervention delivered on phones. This sensitivity to change reflects the intra-personal dynamics and may be telling about the degree to which mindfulness is developed and applied. Given that research around the topic of mindfulness is still developing, recent recommendations have been explicit about using EMA to enhance understanding of the nature and mechanism of this phenomenon (e.g., Moore et al., 2016; Davidson & Kaszniak, 2015). To our knowledge, there have been no EMA studies with cancer patients to investigate the degree of variability in mindfulness states in situ.

Intra-individual variability and mindfulness

Intra-individual variability refers to fluctuations over a relatively short time period (e.g., hours, days) and ways in which individuals respond and adapt to their continuously changing environment (Nesselroade, 1988, 1991). Depending on the context, within-person variability can be adaptive or maladaptive. For instance, high emotional volatility can be indicative of a personality disorder (Ebner-Priemer & Trull, 2009b), while high heart-rate variability is predictive of better health (e.g., La Rovere et al., 2003).

Given that the repeated assessment of mindfulness in the context of daily living is a new area of research, the concept of intra-individual variability has not been yet considered. From prior EMA studies, we understand that within-person fluctuations in mindfulness do take place, both for untrained participants (Brown & Ryan, 2003; Weinstein et al., 2009) and those developing their skills (e.g., Gotink et al., 2016; Snippe et al., 2015). In addition to empirical data, intra-individual variability is supported theoretically. When describing the practice of mindfulness, Wallace (1999) noted that individuals are likely to fluctuate between clear and present and reactive and clouded states. The conceptualization of mindfulness as a continuous process (e.g., Grossman, 2008; Grossman & Van Dam, 2011) or a state in a given moment of time and space (e.g., Brown & Ryan, 2003; Lau et al., 2006; Tanay & Bernstein, 2013) also naturally yields to examination of within-person variability. The unique setting of the current study is that this phenomenon is examined in unique settings of a post-surgical recovery—a period of heightened demand.

Study hypotheses

In the in situ investigation of unfabricated mindfulness among post-surgical lung cancer patients who have not had prior experience or training in mindfulness, we expected to observe a modest degree of mindfulness. Despite the low overall level, we expected to see some variation pointing towards moments when individuals naturally experience mindful states. We were unsure whether this variation will be linked to days of recovery from surgery or inter-personal differences, thus, leaving this an exploratory hypothesis.

Methods

Sample

The present study was part of a larger, prospective, longitudinal, non-randomized study comparing the postoperative health-related quality of life outcomes of stage-I non-small cell lung cancer patients treated with minimally invasive surgery via video-assisted thoracotomy (VATS lobectomy) vs. those treated with standard thoracotomy and lobectomy (THOR). Details of the larger study's sample, detailed inclusion and exclusion criteria, as well as the description of the surgical procedures can be found elsewhere (Rizk et al., 2014). The study was approved by the relevant Institutional Review Board, and all patients signed a consent form for study participation. The study drew from sequential patients presenting at an urban comprehensive cancer center in years 1999–2002 who were diagnosed with non-small lung cancer. Patients were eligible for the trial if they had: (1) histologically confirmed

or suspected clinical stage I non-small cell lung cancer based on standard staging (CT, PET, ± mediastinoscopy); (2) adequate cardiopulmonary reserve to tolerate lobectomy (FEV1 ≥ 40% predicted and DLCO ≥ 40% predicted, no unstable angina or reversible cardiac ischemia on stress test), and; (3) been offered a VATS lobectomy or a standard, posterolateral thoracotomy and lobectomy at the Center (Flores et al., 2009; Rizk et al., 2014; Shiyko et al., 2014). Patients with more advanced stage cancers and those who had undergone a previous lung resection or pre-operative chemotherapy and/or radiation were excluded from the current study.

Of the 88 eligible patients, 81% accepted (n = 71), and 19% declined (n = 17) participation in the current study. Of the 71 patients enrolled, three failed the personal digital assistant (PDA) use proficiency test, which was used for collection of EMA data, and were withdrawn from the study, and two failed to return the PDA and were withdrawn from the study. Of the 66 patients (75%) retained, analyzable data were obtained from 59. Absent data for the seven patients were due to technical problems, such as failure to recharge the PDA's battery or malfunctioning of the PDA itself, or patients not using the PDA as instructed. Thus, the final sample may be slightly biased towards those more dexterous with technology and more adherent to the data collection protocol. Demographically, the final sample was comprised of 36 women (61%), 43 married (73%), with a mean age of 66.1 years old (SD = 7.9). Only three participants reported having some prior experience with either meditation or yoga (one in VATS and two in standard groups). Clinically, 59.3% (n = 35) had a cardiac, endocrinal, pulmonary, and/or renal comorbidity, equally present in patients from both groups. Thirty six patients (61%) underwent the VATS surgery. Following surgery, patients remained in the hospital; the mean stay was 4.48 days (SD = 1.62) for VATS and 5.83 (SD = 3.28) for standard groups ($t_{54.24} = 2.108, p = .040$). Following discharge, all patients were prescribed pain-management medication and were scheduled for a follow-up visit approximately two weeks later.

EMA procedure

While in the hospital, patients were approached by a research team member and consented to participate in the study. Enrolled patients were given a portable palm pilot (PDA) and a user manual, trained to use the device, and provided with a toll-free number for tech support. EMA data collection started immediately following hospital discharge. To encourage participation and address possible questions, patients were contacted by phone on the first, second, and seventh days of data collection. Devices were returned at the follow-up hospital visit.

The EMA schedule included two daily assessments taken over the course of two weeks, scheduled to occur randomly in the first and second halves of the day during individualized waking hours. The relatively low assessment frequency was chosen based on consideration of patient burden in the context of recovery from cancer surgery. All assessments had to be completed within a 10-minute window after the alarm had sounded. Missed assessments could not be made up to avoid bias in oversampling symptom-free, convenient life experiences. All responses were time and date stamped.

Measures

Mindfulness was assessed with four items adapted from the earlier version of the Toronto Mindfulness Scale (Bishop et al., 2004; see also Lau et al., 2006), developed for the assessment of states. In EMA studies, it is recommended to use short versions of scales to enhance compliance and avoid participant drop-out, a practice adapted by other EMA studies on mindfulness (Brown & Ryan, 2003; Snippe et al., 2015; Vilardaga et al., 2014; Weinstein et al., 2009). Items included: "Just now, I noticed when I became lost in my thoughts, daydreams or fantasies" (reversed); "Just now, I found myself observing unpleasant feelings without getting drawn into them,;" "Just now, I noticed how my mind tended to cling to certain thoughts and feelings that I was experiencing;" and "Just now, I was open to whatever thoughts and feelings I was experiencing" (the response scale extended from 0—"not at all" to 4—"very much"). Based on prior work (Bishop et al., 2004; Lau et al., 2006) and face validity, the items measured a momentary degree of awareness of one's internal experience of thoughts and feelings with the quality of self-non-identification with those experiences. Based on Cronbach's alpha, internal consistency of four items was .65. When the last item was removed, alpha increased to .80. Thus, in our analysis we used an average of three items.

Prior experience with mindfulness was assessed with a single dichotomous item, asking if participants have prior experience with meditation or mindfulness practices

Statistical analysis and results

Analytic plan

Following the standards for EMA data reporting (Stone & Shiffman, 2002), we first examined adherence to the EMA protocol. An average adherence rate for each individual was computed as the number of assessments completed divided by the total number of assessments expected (twice a day for 2 weeks = 28). A general liner model was used to

examine factors contributing to adherence, with rates of adherence as the outcome and demographic characteristics and surgery type (VATS vs. THOR) as predictors. A generalized multilevel model (MLM, de Deleeuw & Meijer, 2007; Rodriguez, 2008) was used to examine temporal patterns in adherence, with adherence to a momentary assessment (yes/no) modeled as a function of days in the study (0–13), time of the day (morning vs. afternoon), demographics and surgery type.

Next, we examined within-person level and net variability in mindfulness states and between-person differences. The within-person level of mindfulness was quantified as a mean of all EMA assessments for a given individual. Drawing on previous research from the field of emotions (e.g., Keng & Tong, 2016), the net within-person variability in mindfulness was defined as a standard deviation of all mindfulness scores for a given individual. Descriptive statistics were computed for sample-based distributions of within-person levels and net variability. Inter-individual differences in levels and dispersion were assessed in two linear regression models with individual-level means and standard deviations as outcomes and demographic variables, indicators of prior level of experience with mindfulness or yoga, adherence rates and surgical group as predictors. Of note, the distribution of mean mindfulness scores was positively skewed (Skew/SE = 1.56/.31 = 5.03) and normalized by taking a square root.

Finally, to unpack net variability, we examined temporal sources of variation in momentary mindfulness states. A variance partitioning approach in the context of MLM described in Shiyko and Ram (2011) was used to test four sources of variation: within a day (morning/evening), between study days, between weeks (first and second), and between individuals. Conceptually, the total amount of variance is split between the defined sources of variability or levels in MLM (i.e., individual, week, etc.), each of which is tested for significance. This approach is analogous to spectral decomposition, only for EMA data, where different frequency bands (in this case, weeks and days) are examined for sources of variation. A natural logarithm of the outcome was used to account for non-normality. Within-day variation wasn't found to be significant and was dropped from the final model.

Results

Adherence

Across the two weeks of the data collection period, a total of 1007 momentary reports of mindfulness were collected. On average, every participant provided 17.07 momentary assessments (Md = 18, SD = 6.99, Range = 3–28). The average adherence rate was 61% (Md = 64%, SD = 25%). Based on the results of linear regression, adherence rate did not depend on any of the demographic variables; however, participants in the VATS group exhibited marginally lower adherence rates by about 11% (SE = .065, $p = .089$) compared to the THOR group (65%, SE = 4.1).

Based on the results of the generalized MLM, the likelihood of responding to a momentary mindfulness question decreased over days in a linear fashion ($\beta = -.077$, $p = .014$) for the entire sample (see Fig. 1). In addition, the time of the day had an effect on the probability of a response, with afternoon assessments having a lower likelihood of completion ($\beta = -.424$, $p < .001$). Finally, patients in the THOR group were more likely to complete their momentary assessment overall ($\beta = .875$, $p = .006$), which manifested in a higher baseline completion likelihood ($p < .01$) maintained over time

Person-specific levels and net variability in mindfulness

Based on the distributions of person-based mean and standard deviation scores, the level of mindfulness for this sample averaged at .49 (Md = .33; SD = .51; Range: 0–2.51), and within-person net variability was estimated to be .42 (Md = .38, SD = .26; Range: .00–1.30). Correlation between individual levels of mindfulness and net variability was .774 ($p < .001$).

Based on results of linear regression, older individuals tended to report lower levels of mindfulness overall ($\beta = -.01, SE = .006, p = .081$). For the model predicting within-person variability in mindfulness, higher variability

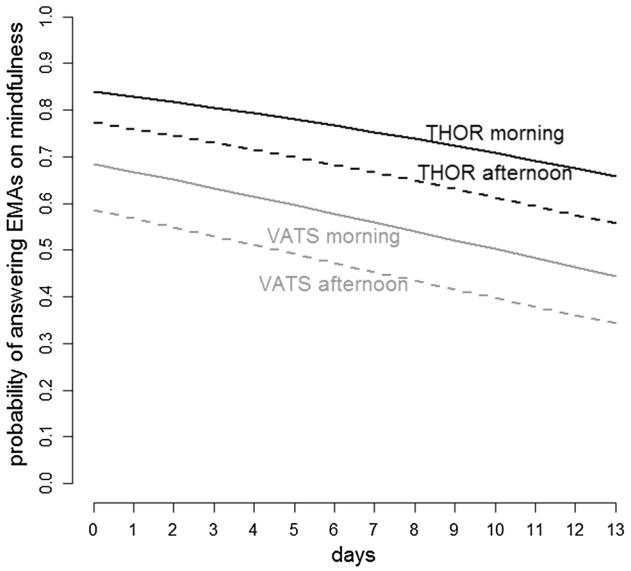

Fig. 1 Estimated mean trajectories from the generalized mixed-effects model assessing the likelihood of EMA completion as a function of days in the study, time of the day, and a surgical group (THOR—traditional thoracotomy; VATS—video-assisted thoracotomy)

was found in individuals in the VATS group compared to the standard surgical group (a difference of .18 points, SE = .067, p = .012). Older individuals had lower levels of net variability ($\beta = -.008, SE = .004, p = .049$).

Sources of variation in mindfulness scores

Based on the variance partitioning approach, the variance in mindfulness scores was split as follows: .2% due to week-to-week variation, 2.2% due to between-day variation, and 41.4% due to between-individual variation. The remaining 56.2% was unexplained and could be due to either systematic, contextual fluctuations or inherently stochastic processes.

Discussion

Lung cancer is one of the most common types of cancers; one in 13 men and one in 16 women develop it during a lifetime (American Cancer Society, 2014–2015). Cancer diagnosis, in general, is a transitional life period, characterized by heightened psychological needs and stressors (Institute of Medicine, 2008). There is much interest in helping newly diagnosed cancer patients with coping and recovery. This study contributed to existing literature by obtaining unique data gathered in real-life settings in a sample of newly diagnosed stage I lung cancer patients recovering from surgery after hospital discharge. We examined the capacity of patients to demonstrate the innate predisposition towards mindfulness, referred to as unfabricated mindfulness, characterized by ability to be aware of one's inner states (e.g., thoughts, feelings) without identifying with those states. Patients in this study were recovering from cancer surgery, had not been formally trained in mindfulness (and, indeed, had little casual exposure), and were repeatedly assessed twice a day over two weeks through the methodology of ecological momentary assessments. These data were used to examine within-person levels, fluctuations and inter-individual differences in mindfulness.

Based on our findings, the overall level of mindfulness was very low, with most individuals reporting being not at all or a little mindful. The distribution of EMA responses was highly positively skewed, with about half of the assessments at the level of "not at all mindful" and a quarter—at the minimal level ("a little"). Thus, most of the time, individuals were drawn into their thoughts or unpleasant feelings, unable to maintain a distance from them.

Overall, results indicate that, during post-surgical recovery, untrained cancer patients are generally unlikely to exhibit predispositional or unfabricated mindfulness, which is consistent with our hypothesis. This is in contrast with younger and healthy populations (Brown & Ryan, 2003; Weinstein et al., 2009). While previous studies have not explicitly examined the degree of mindfulness in daily life, momentary states have been used to predict other outcomes of interest, indicating at least some degree of variability. Future research would benefit from direct comparisons to understand population differences. Notably, participants in our study were older, with the mean age of 66.1 years old, compared to 37.6 years in Brown and Ryan (2003) and 20 years in Weinstein et al. (2009).

Further, we examined intra-individual variability in mindfulness to understand stability of the construct across time. Based on our hypotheses, we expected to see some degree of within-person fluctuations. The mean net variability was .42, indicating that, overall, approximately 95% of momentary responses fluctuated within a point from their average on the 1–5 Likert scale. The range in variability spanned from 0 to 1.3, show casing participants for whom mindfulness did not vary at all (SD = 0) and those with substantial fluctuations (SD = 1.3). Interestingly, those with higher levels of mindfulness also had higher intra-individual variability. Thus, it appears that individuals who are somewhat mindful are not uniformly consistent in exhibiting this quality in daily life. In addition, older individuals had lower variability in mindfulness. The effect of age should be further examined to understand if aging plays a role.

Next, based on the multi-level variance partitioning model, we found that 41.4% of the total variance in mindfulness can be attributed to inter-personal and 58.6% to intra-personal factors. Analogous to spectral analysis decomposition for time-series data, the model identifies portions of variance attributable to systematic, periodic cycles. In our case, we examined the impact of days and weeks, with 2.2 and .2% of variance attributable to each, respectively. This is insubstantial, as the remaining 56.2% are due to moment-to-moment fluctuations and stochastic error. Understanding momentary fluctuations, in future studies, would require examination of contextual factors.

Increasingly, there have been recommendations promoting the use of EMA methodology with mindfulness research (Davidson & Kaszniak, 2015; Moore et al., 2016; Sauer et al., 2013). It is based on the underlying assumption that state mindfulness is dynamic and variable. Our findings demonstrate that this may not be universally true and could dependent on the population under investigation and the context. For untrained individuals during a stressful life event such as cancer, it appears that twice-a-day assessments either doesn't capture instances of mindful states or point towards absence of those states. A more rigorous investigation is needed to confirm this finding, where

mindfulness states are oversampled (e.g., 5–10 assessments per day) and examined for stability across hours and days (see Shiyko & Ram, 2011; Collins, 2006 for further discussion on the study design and interpretation). We have previously introduced the concept of "process speed" (Shiyko & Ram, 2011), signifying that within-person processes can change at different rates. Some processes (e.g., emotions) are highly labile, while others are slower. Understanding process speed for mindfulness has implications for study design and participant burden.

Based on research in other fields (e.g., Baird, Le, & Lucas, 2006; Ebner-Priemer & Trull, 2009b; Larsen, 1987; Nesselroade & Ram, 2004), within-individual variability seems to capture a part of a dynamic process not captured by average scores. In the context of mindfulness research, future studies can examine net variability in several ways. First, it is interesting to investigate how variability changes, as participants acquire mindfulness skills. It is possible that variability itself can be in indicator of mastery. Analogous to the classical Piagetian theory of cognitive development, as children move across stages, the shift in development is accompanied by variability (Piaget, 1964). Thus, a combination of both, the level and variability can be indicative of mastery and applications of mindfulness skills in life. A second avenue of investigation is examination of predictive power of net variability on outcomes of interest. In the current study, we did not have distal outcomes to test such hypotheses; yet they can be informative for the field.

In conclusion, it is noteworthy to mention some limitations of the current work. The study was a branch of the parent study, which focused primarily on clinical effects of two surgical procedures (Rizk et al., 2014). Thus, the current study had limited information on individual-level factors directly related to mindfulness. For instance, the study would have benefited from a more in-depth investigation of personality traits. Further, given the population of the study, we had to consider burden and feasibility, and were limited in the number and frequency of ecological momentary assessments. Adherence in the current sample was reasonable and comparable to other EMA studies (Shiyko, Perkins & Caldwell, in press), indicating feasibility of using twice a day assessment paradigm with a vulnerable sample. Yet, future work should not only consider a more frequent assessment but also design questions targeting mindfulness and related constructs directly. Next, the current study relied on previous practices of adapted existing questionnaires to the EMA design and, thus, did not develop or validated EMA measures. Given the sample size, we also could not confirm dimensionality of the mindfulness items. Further, technological difficulties, including failure to charge batteries or device malfunctioning, might have resulted a biased sample due to missing data. Finally, since the sample was predominantly White and well-educated, further studies should examine robustness of the results across cultures, ethnical backgrounds, and social standing.

Overall, this is the first study to examine mindfulness states in real time and real life in a sample of stage I lung-cancer patients recovering from surgery. Findings demonstrate that repeated sampling of mindfulness states in natural settings uncover important aspects of the process related to within-person variability, systematic and non-systematic fluctuations, and between-individual differences. These findings can inform theoretical and methodological conceptualization of studying mindfulness in general and patient populations.

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Compliance with ethical standards

Conflict of interest Mariya P. Shiyko, Brian Siembor, Paul B. Greene, Joshua Smyth, and Jack E. Burkhalter declare that they have no conflict of interest.

Human and animal rights and Informed consent All procedures were in accordance with the ethical standards of the institutional research committees and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

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