Understanding change in psychological treatments for depressive symptoms
Snippe, Evelien

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The order of change in mindfulness, repetitive thinking, and depressive symptoms during mindfulness-based treatment: a time-series study

E. Snippe, E.H. Bos, K.M. van der Ploeg, R. Sanderman, J. Fleer, M.J. Schroevers

Submitted
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Abstract
Mindfulness and ruminative thinking have been shown to mediate the effects of mindfulness-based treatments on depressive symptoms. Yet, the dynamic interplay between these variables in daily life during mindfulness-based treatment has received little attention. The present study focuses on the sequence of daily changes taking place within individuals during a mindfulness-based treatment. Using a replicated single-subject time-series design, we examined the within-person temporal associations between day-to-day changes in mindfulness, repetitive thinking, and depressive symptoms. Study participants were six women with depressive symptoms who filled out diary questionnaires during a mindfulness-based treatment. A separate vector autoregressive (VAR) model was estimated for each participant. Changes in mindfulness and repetitive thinking preceded changes in depressive symptoms in a few of the participants. We did not find evidence for reverse causality; changes in depressive symptoms did not predict later changes in mindfulness or repetitive thinking in any of the participants. All individuals showed moderate to strong concurrent (within-day) associations between the variables. The results do not undermine the assumed causal chain of change but suggest that the studied change process may be operating fast as daily changes seemed to go together.
Interest in mindfulness-based treatments, such as Mindfulness-Based Cognitive Therapy (MBCT) and Mindfulness-Based Stress Reduction (MBSR), for the alleviation of depressive symptoms has increased in the past decade. Empirical evidence suggests that both MBCT and MBSR are effective in reducing depressive symptoms (e.g., Khoury et al., 2013). It is assumed that mindfulness-based treatments promote the development of mindfulness, and that improvements in mindfulness subsequently relieve distress (Bishop et al., 2004). Only recently, researchers have started to investigate this assumed mechanism underlying mindfulness-based treatments. Indeed, it was found that the development of mindfulness skills is enhanced in MBCT (Schroevers & Brandsma, 2010) and MBSR (Nyklíček & Kuijpers, 2008). Moreover, two randomized controlled trials showed that increased levels of mindfulness mediated the impact of MBCT on depressive symptoms (Kuyken et al., 2010; Shahar, Britton, Sbarra, Figueredo, & Bootzin, 2010).

Besides mindfulness, decreased ruminative thinking has been proposed to explain the benefits of mindfulness-based treatments for depression. Segal, Williams and Teasdale (2002) suggest that MBCT trains individuals to disengage from negative experiences and to shift attention to present-moment experiences. These skills are believed to interfere with ruminative ways of thinking. Controlled studies have indeed found that different forms of repetitive thinking, such as rumination and worry, mediate the effect of mindfulness-based treatments on depressive symptoms (e.g., van Aalderen et al., 2012) and distress (Jain et al., 2007).

A drawback of the above-mentioned studies is that they do not provide insight in within-person change processes occurring during mindfulness-based treatment or the possibility of reverse causality. In most of these studies the assumed mediator and outcome were measured at only two time points (i.e., pre-treatment and post-treatment). Therefore, the mediation analyses were actually performed on cross-sectional data (Singer & Willett, 2003). With such an analysis, the temporal ordering and thus the causal direction of the effects cannot be established. It thus remains unclear if changes in mindfulness and repetitive thinking precede or follow changes in depressive symptoms, or both. To infer the temporal ordering of the assumed mechanism, it is necessary to obtain multiple measurements over the course of treatment (e.g., Laurenceau, Hayes, & Feldman, 2007) and to examine whether an assumed mechanism operates before the outcome variable changes (Kazdin, 2007).

Another problem that may arise is that most studies investigated mechanisms of change at the group level. Within-person associations may
not be adequately captured with a between-subjects design, as aggregating data across subjects may blur processes operating within individuals (Hamaker, 2012; Molenaar, 2004). Also, several studies have shown that within-person associations may differ across individuals (Molenaar, 2004; Rosmalen, Wenting, Roest, de Jonge, & Bos, 2012). Heterogeneity in within-subject processes may go unnoticed in studies with a between-subjects design and the effects might be canceled out or diluted because of these differences (Hamaker, 2012). It has therefore been recommended to examine psychological change processes within individual subjects over time (Barlow & Nock, 2009) and to investigate individual differences in therapeutic change processes (Kazdin, 2007). Recently, it has been suggested that individual differences in response to meditation exist, advocating single-subject designs in the field of mindfulness meditation research (May, Weyker, Spengel, Finkler, & Hendrix, 2014).

A replicated single-subject time-series approach is particularly suitable for studying the temporal order of change within individuals over time. With this approach, it can be studied if changes in one or more variables systematically predict changes in another variable (Hamaker, Dolan, & Molenaar, 2005). For example, it can be investigated if increases in mindfulness are followed by depressive symptoms on subsequent time points in a particular individual. With such an approach, one is able to make inferences about the temporal order of change at the person level by aggregating data across time points instead of across subjects (Hamaker, 2012). The power of such single-subject time-series studies depends on the number of assessments per individual instead of the number of individuals included in the study (Hamaker, 2012). Time-series analysis of daily self-report assessments over the course of treatment has been shown very suitable for studying therapeutic change processes at a micro-level in individuals (see e.g., Dugas, Francis, & Bouchard, 2009).

The aim of the current study is to examine (1) if day-to-day changes in mindfulness and repetitive thinking precede day-to-day changes in depressive symptoms within individuals, (2) whether reverse effects occur, with changes in depressive symptoms preceding changes in mindfulness and repetitive thinking, and (3) whether there are individual differences in the effects. A replicated single-subject time-series design is used to gain detailed insight into the temporal order of change taking place within individuals and individual differences in the studied processes. The study was performed in persons experiencing depressive symptoms who participated in a mindfulness-based treatment as changes in the variables under study are most likely to occur in this context. We hypothesized that for
most of the individuals day-to-day changes in mindfulness and repetitive thinking predict subsequent changes in depressive symptoms, and not the other way around.

Method
Design
The present study used a replicated single-subject time-series design. The study was performed in a naturalistic treatment setting in which patients with a variety of psychiatric disorders receive a combination of Mindfulness-Based Cognitive Therapy (MBCT) and Mindfulness-Based Stress Reduction (MBSR). The current study focused only on those patients with at least mild depressive symptoms. Measures were obtained on a daily basis.

Participants and procedure
Participants were recruited at Mental Health Institution Lentis, Center for Integrative Psychiatry, Groningen, The Netherlands. Study approval was obtained from the Medical Ethical Committee for mental health institutions in the Netherlands. Inclusion criteria were enrolment in the mindfulness-based treatment, the presence of at least mild depressive symptoms (Patient Health Questionnaire-9 (PHQ-9) ≥ 5) (Kroenke, Spitzer, & Williams, 2001), and age ≥ 18 years. Exclusion criteria were: organic brain damage, mental retardation, bipolar disorder, psychotic disorder, eating disorder, suicidal ideation, substance abuse, concurrent psychotherapy, and stable use of an antidepressant/changes in use of antidepressant medication ≤ 2 months.

All consecutive patients who enrolled in the mindfulness-based treatment during the recruitment period (between February 2012 and September 2012) were asked if they consented to be approached for an ongoing study. We contacted patients who did not meet exclusion criteria by telephone to screen for depressive symptoms (using the Patient Health Questionnaire-2). If participants indicated to suffer from a depressed mood or a loss of interest during the last two weeks, and patients were interested in study participation, written information on the study was sent by mail.

Patients who gave written informed consent for study participation were invited for a face-to-face briefing session at the start of the study. First, participants filled out the PHQ-9 (Kroenke et al., 2001) and several questions on demographic variables. Participants were excluded from the study if the PHQ-9 score was lower than 5. Second, we explained the meaning of the diary questions and rating of the answer categories.
Participants were given the possibility to fill out the diary questions either online or on paper. The participants were instructed to fill out the daily questions at a fixed time at the end of each day, starting two weeks before the first session of the mindfulness-based treatment (baseline phase) until the last session of the treatment (intervention phase). A baseline phase of two weeks was included to cancel out possible changes induced by filling out the diary; these two weeks were excluded from the analyses. Participants who filled out the diary questions on paper were asked to return the diaries by mail on a weekly basis. To promote compliance, participants were informed that they would receive a report of their individual results at the end of the study period. All participants were compensated for their efforts by a reward in the form of a meditation cushion or bench. In addition, a financial incentive of 50 euro was given to those who completed at least 90% of the daily questions. We contacted participants several times during the study period to review and encourage completion of the diary. At the end of the study period, participants were invited for an interview to evaluate the mindfulness-based treatment and to discuss their individual results of the study.

During the recruitment period, 52 patients diagnosed with a variety of disorders enrolled in four mindfulness group programs. Twenty-eight of these patients gave written consent to be approached for an ongoing study, of which 8 patients met an exclusion criterion; 1 patient received other psychological treatment, 2 patients used antidepressants for less than 2 months, 3 patients were diagnosed with an eating disorder, 1 patient reported substance abuse and 1 patient suffered from psychotic symptoms in the past. Of the remaining 20 patients, 7 did not fulfill the inclusion criterion of reporting depressive symptoms in the telephone interview and 2 could not be reached by telephone. Thus, in total, 11 patients were eligible for the study. The majority of these participants (9) gave written informed consent for taking part in the study. After start of treatment, 2 of these 9 participants were excluded as they became ineligible: one participant dropped out of the mindfulness-based treatment and the study after two weeks because of a depressive relapse and another participant quit antidepressant medication during the study period. Only one participant was excluded from the analyses because her data did not meet the assumptions for analysis (no daily variability in the data and < 50 days of questionnaire completion (n=36)). Our final sample consisted of 6 participants. Four of the six participants completed the diary questions online, two completed them on paper. All participants completed the daily questions on at least 95% of the days.
Treatment
The intervention was a standardized group program based on the Mindfulness-Based Stress Reduction program (MBSR) (Kabat-Zinn, 1990), supplemented with several exercises from the Mindfulness-Based Cognitive Therapy (MBCT) protocol (Segal et al., 2002). The mindfulness-based treatment consisted of 8 standardized group sessions of 2.5 hours over 8 to 10 weeks and a silent retreat session.

The mindfulness trainers followed a structured treatment protocol in which the components for each session are prescribed. Following the MBSR and MBCT protocols, all group sessions included one or more formal mindfulness exercises (e.g., body-scan, sitting meditation, yoga exercises), a discussion of participants’ experiences during the exercises, an evaluation of experiences during homework exercises, and assignment of homework exercises for next week. MBCT-specific elements included the automatic thoughts questionnaire, the thoughts and feelings exercise, the 3-minute breathing space and developing an action plan (relapse prevention). Homework was assigned for 45 minutes to 1 hour a day and the central role of home practice was repeatedly stressed by the mindfulness trainers. All participants received the same workbook including homework assignments per week, registration forms and information on the themes of the sessions (see Kabat-Zinn, 1990; Segal et al., 2002). The mindfulness-based treatment was delivered in four different groups during the study period by four different certified mindfulness trainers who provided mindfulness programs at least twice a year for at least 4 years.

Measures
Demographic and clinical characteristics
Demographic variables were obtained using a self-report questionnaire and included gender, age, marital status, level of education, and employment. Information on the participants’ clinical diagnosis (made by a psychiatrist within 3 months before the mindfulness training), use of antidepressants, and concurrent provided care were obtained from patients’ medical records.

Diary
Daily levels of depressive symptoms, mindfulness, and repetitive thinking were assessed using a diary. The variables under study were measured with a total of eight items selected from widely used and well-validated questionnaires that measured the constructs of interest. Only a few items were selected per construct since lengthy diaries enhance noncompli-
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ance (Morren, van Dulmen, Ouwerkerk, & Bensing, 2009) and may result in drop-out (Thiele, Laiereiter, & Baumann, 2002), and it has therefore been recommended to make diaries simple in use (Thiele et al., 2002). The selection of items was made based on the factor loadings in validation studies and face validity. The items were adapted for daily use. The diary also included space for participants to report events that might have influenced their diary responses.

Daily depressive symptoms were measured with the validated Patient Health Questionnaire-2 (PHQ-2) (Kroenke, Spitzer, & Williams, 2003; Spitzer, Williams, & Kroenke, 2013), which is based on the two core symptoms of depression according to the Diagnostic and Statistical Manual of Mental Disorders (4th edition) (American Psychiatric Association, 1994). The two questions assess a depressed mood (“I felt down, depressed or hopeless”) and anhedonia (“I had little interest or pleasure in doing things”), which were rated on a 7-point likert scale ranging from 1 (not at all) to 7 (very much). The criterion validity and construct validity of the PHQ-2 were supported in previous research (Kroenke et al., 2003).

Two central aspects of mindfulness, awareness and non-judging, were assessed with items from the Five Facet Mindfulness Questionnaire (FFMQ) (Baer, Smith, Hopkins, Krietemeyer, & Toney, 2006). The choice for these two aspects was based on the commonly used definition of mindfulness, i.e., being aware of present moment experiences without judging (Bishop et al., 2004; Kabat-Zinn, 1994), the evidence showing that these are elements of the mindfulness construct (Baer et al., 2006), and their predictive value in predicting psychological symptoms (Baer et al., 2008; Baer et al., 2006). Awareness was assessed with two items with high factor loadings (0.61 respectively 0.67) on the awareness scale of the FFMQ (Baer et al., 2006). The items included in the diary were: “I rushed through activities without being really attentive to them” and “I did jobs or tasks automatically without being aware of what I was doing”. Non-judging was measured with the two items with the highest factor loadings (0.73 respectively 0.69) on the non-judging scale of the FFMQ (Baer et al., 2006); “I thought some of my emotions were bad or inappropriate and I shouldn’t feel them” and “I made judgments about whether my thoughts were good or bad”. The questions were rated on a 7-point likert scale ranging from 1 (not at all) to 7 (very often/all of the time). The measure of mindfulness was based on the mean of the recoded ratings on awareness and non-judging so that high scores indicate high levels of mindfulness.

Repetitive thinking was measured with two items with high factor loadings (0.83 respectively 0.85) on the higher order factor that represents
the core characteristics of repetitive negative thinking in the Dutch Perseverative Thinking Questionnaire (PTQ) (Ehring et al., 2011). Studies supported the construct validity of the PTQ (Ehring et al., 2011). The included items were: “The same thoughts kept going through my mind” and “I got stuck on certain issues and couldn’t move on”. Both items were rated on a 7-point likert scale ranging from 1 (not at all) to 7 (very often/all of the time).

Statistical analyses
Vector Autoregressive Modeling (VAR)
To study the temporal associations between the variables we conducted Vector Autoregressive Modeling (VAR) using STATA 11.0. A VAR model consists of a set of regression equations, in which each of the endogenous variables is regressed on its own lagged values (autocorrelation) as well as the lagged values of the other variables (cross-correlation) (Brandt & Williams, 2007; Rosmalen et al., 2012; Sims, 1980). In this way, the dynamic effect of time series variables on each other can be assessed, taking into account potential bidirectional associations as well as autocorrelation in the time series (Brandt & Williams, 2007). A separate VAR model was estimated for each individual study participant. The VAR model included depressive symptoms, repetitive thinking, and mindfulness as endogenous variables, which means that these variables are treated as both predictor and outcome. To control for the possible confounding influence of the days of the week and other extraordinary events reported by participants (such as illness or menstruation), these factors were included as exogenous variables in the VAR models, using dummy variables. Exogenous variables serve only as predictors, not as outcomes. We also included a variable denoting the time (0,1,2,3,…t) and the square of time as exogenous variables to the model, to arrive at series that are stationary.

The optimum number of lags (i.e., the number of past days taken into account) for each VAR model was selected based on goodness-of-fit criteria, i.e., the final prediction error (FPE), Akaike Information Criterion (AIC), Hannan-Quinn Information Criterion (HQIC), and Bayesian Information Criterion (BIC) (Brandt & Williams, 2007). If a lag of 2 was indicated by the majority of the goodness-of-fit criteria, predictors at both lag 1 and 2 were included in the model. For four of the six individual VAR models, a lag length of 1 day was optimal. A lag length of 2 days was found optimal for one participant and a lag length of 3 days for another participant.

The VAR models were estimated with the missing values embedded in the series. Constraints were set on the parameter coefficients that
did not contribute significantly to the VAR model (Lütkepohl, 2007), starting with the coefficients with the highest p-values, until all coefficients with a p-value larger than 0.25 were constrained. The residuals of the final VAR models were checked on the assumptions of independence, homoscedasticity, and normality. If any of these assumptions was violated, the model was adjusted and re-estimated until all assumptions were met.

**Granger causality**
Based on the individual VAR models, Granger causality tests were performed to examine whether changes in mindfulness and/or repetitive thinking ‘Granger cause’ changes in depressive symptoms, or the other way around. When a variable A ‘Granger causes’ variable B, this means that more variance in B is explained based on past values of both A and B than on past values of B only (Granger, 1969). The causality tests were performed on pairs of the variables of interest.

**Concurrent associations**
In the VAR models, only lagged associations are modeled, without taking into account the concurrent (i.e., within-day) associations. This is done to separate the dynamic part from the simultaneous part of the model, because the order of the concurrent associations cannot be established. To examine the strength of the concurrent associations between mindfulness, repetitive thinking, and depressive symptoms, within-day correlations were calculated by correlating the residuals of the VAR models (Brandt & Williams, 2007).

**Orthogonalized Impulse Response Functions (OIRFs)**
To test whether the lagged associations found in the VAR models are robust when taking into account the concurrent associations, we examined the Orthogonalized Impulse Response Functions (OIRFs). OIRFs show the change in an endogenous variable over the course of several days in response to an isolated shock in one of the other endogenous variables (Brandt & Williams, 2007). OIRFs are based on the cross-lagged associations of the VAR model, but also take into account the concurrent associations between the variables. As we do not know the causal order of the concurrent associations, two OIRFs were computed, each with a different assumed order of the concurrent associations. When the lagged associations found in the VAR model disappear in one of the OIRFs, this indicates that the lagged effects are overshadowed by the concurrent associations. Lagged effects were therefore considered to be robust when the effects
were significant in both the VAR model and the OIRFs.

**Results**

**Descriptives**

The study participants were six women, aged between 31 and 63, and diagnosed with a depressive disorder, a generalized anxiety disorder, or an adjustment disorder (see Table 1). Participants 1, 2, 4, and 5 reported mild depressive symptoms (i.e., score 5-9) and participants 3 and 6 reported moderate depressive symptoms (i.e., score 10-14) at the start of the treatment and baseline period (Kroenke et al., 2001). The time series of all participants are depicted in Figure 1. The time trends in the outcome variables over the course of treatment (as estimated in the VAR models) are shown in Table 2. In participants 3, 4, and 6, a significant decrease in depressive symptoms was observed over the course of the mindfulness-based treatment (see Table 2). Visual inspection of Figure 1 reveals low mean levels of depressive symptoms in participant 2 (soon after the start of the mindfulness-based treatment), and participant 5 (except for some days on which she reported high levels of depressive symptoms). In participant 1, no improvement in depressive symptoms occurred over the course of the treatment. In the post-treatment interview, this participant 1 reported that she developed Meniere's disease during the study period, which was very disabling for her and seemed to have enhanced her depressive symptoms. Regarding repetitive thinking, a decrease over time was observed in participants 2, 3, and 6. In participants 2, 3, 4, and 6, a significant increase in mindfulness was observed over the course of the treatment.
### Table 1. Characteristics of the study participants

<table>
<thead>
<tr>
<th>Part</th>
<th>Age</th>
<th>Marital status</th>
<th>Educational level</th>
<th>Employment</th>
<th>Diagnosis</th>
<th>Anti-depressant</th>
<th>PHQ-pre</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>53</td>
<td>Married</td>
<td>Vocational</td>
<td>Disabled</td>
<td>MDD</td>
<td>-</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>31</td>
<td>Married</td>
<td>Vocational</td>
<td>Disabled</td>
<td>GAD</td>
<td>Lexapro</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>37</td>
<td>Single</td>
<td>Higher education</td>
<td>Disabled</td>
<td>MDD, in remission</td>
<td>-</td>
<td>11</td>
</tr>
<tr>
<td>4</td>
<td>49</td>
<td>Divorced</td>
<td>Higher education</td>
<td>Employed</td>
<td>GAD</td>
<td>Mirtazapine</td>
<td>7</td>
</tr>
<tr>
<td>5</td>
<td>35</td>
<td>Living together</td>
<td>Higher education</td>
<td>Taking care of children</td>
<td>AD with depressed mood</td>
<td>-</td>
<td>8</td>
</tr>
<tr>
<td>6</td>
<td>63</td>
<td>Single</td>
<td>Higher education</td>
<td>Retired</td>
<td>MDD, recurrent, in remission</td>
<td>Efexor</td>
<td>10</td>
</tr>
</tbody>
</table>

*Note.* Part = participant number; MDD = Major Depressive Disorder; GAD = Generalized Anxiety Disorder; AD = Adjustment Disorder; PHQ pre = Patient Health Questionnaire-9 (PHQ-9) score at the start of the baseline phase; PHQ-9 scores can range from 0 (no depressive symptoms) to 27 (severe depressive symptoms).

### Table 2. Time trends over the course of treatment

<table>
<thead>
<tr>
<th></th>
<th>Part 1</th>
<th>Part 2</th>
<th>Part 3</th>
<th>Part 4</th>
<th>Part 5</th>
<th>Part 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depression (trend)</td>
<td>↓</td>
<td>↓</td>
<td>↓</td>
<td>↓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Repetitive thinking (trend)</td>
<td>↓</td>
<td>↓</td>
<td></td>
<td>↓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mindfulness (trend)</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length of time series (n)</td>
<td>78</td>
<td>78</td>
<td>75</td>
<td>63</td>
<td>65</td>
<td>56</td>
</tr>
<tr>
<td>Missing observations (n)</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

*Note.* Arrows pointing upwards denote an increase in the outcome measure over time; arrows pointing downwards denote a decrease over time. Time trends are as estimated in the VAR models using variables for Time and the square of Time. Only significant trends are shown (p < 0.05).
Figure 1. Time series of the participants

Note. The length of the series differed between individuals because the mindfulness-based treatments were given over a period of 8 to 11 weeks.
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Temporal associations
The results of the Vector Autoregressive (VAR) models and Granger causality tests are presented simultaneously in Table 3. In most participants, only a few lagged associations were found. The VAR model of participant 6 was exceptional, with several bidirectional associations between the variables. Some of these associations disappeared when both the lagged and the concurrent associations were taken into account in the Orthogonalized Impulse Response Functions (OIRFs) (see Table 3). This indicates that the lagged effects were overshadowed by the concurrent associations and were therefore not considered to be robust. For the sake of clarity, we only describe below the lagged associations that remained robust in the OIRFs.

For two out of six participants (3 and 6), we found that decreases in repetitive thinking were followed by decreases in depressive symptoms the next day (participant 3) and two days after (participant 6). No temporal associations in the opposite direction were found: changes in depressive symptoms were not followed by changes in repetitive thinking in any of the participants.

Regarding mindfulness and depression, the results of only one of the six participants (2) robustly showed that increases in mindfulness were followed by decreases in depressive symptoms the next day. No temporal associations in the reverse direction were found in any of the participants.

Concerning mindfulness and repetitive thinking, the models of three participants (1, 2, and 4) showed that increases in mindfulness were followed by later decreases in repetitive thinking. For one participant (6), it was found that increases in mindfulness predicted increases in repetitive thinking three days after. No robust associations in the reverse direction were found; changes in repetitive thinking were not followed by changes in mindfulness.

Concurrent associations
Because, as described above, some of the lagged associations were overshadowed by the concurrent associations, we performed additional analyses and examined the strength of the concurrent associations. The within-day correlations between the variables were mostly large and the sign of the correlation coefficient was as expected and similar for all participants (see Table 4). On days that participants were more mindful, they reported less repetitive thinking and felt less depressed. The negative concurrent association between mindfulness and depressive symptoms was large in five of the six participants (according to the effect sizes provided by Cohen (2003)), and medium in participant 2. The positive correlation between
repetitive thinking and depressive symptoms was large in three participants, medium in two participants and not significant in one participant. The negative correlation between mindfulness and repetitive thinking was large in all participants.

### Table 3. Granger causality tests and estimates from the VAR models

<table>
<thead>
<tr>
<th>Granger causality</th>
<th>Estimates (B)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Part 1</td>
</tr>
<tr>
<td>Repetitive thinking → Depression</td>
<td>-</td>
</tr>
<tr>
<td>Depression → Repetitive thinking</td>
<td>-</td>
</tr>
<tr>
<td>Mindfulness → Depression</td>
<td>-</td>
</tr>
<tr>
<td>Depression → Mindfulness</td>
<td>-</td>
</tr>
<tr>
<td>Mindfulness → Repetitive thinking</td>
<td><strong>-0.32</strong></td>
</tr>
<tr>
<td>Repetitive thinking → Mindfulness</td>
<td>-</td>
</tr>
<tr>
<td>Lag of explanatory variable</td>
<td>t-2</td>
</tr>
</tbody>
</table>

*Note.* The VAR estimates are shown in case the Granger causality test for that association was significant (*p*<0.05), meaning that the first variable ‘Granger causes’ the second variable. In bold: the lagged associations that remained significant in the Orthogonalized Impulse Response Functions. Part = participants.

### Table 4. Concurrent (within-day) associations

<table>
<thead>
<tr>
<th>Concurrent association</th>
<th>Correlation coefficient (r)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Part 1</td>
</tr>
<tr>
<td>Mindfulness and Depression</td>
<td>-0.65</td>
</tr>
<tr>
<td>Repetitive thinking and Depression</td>
<td>0.57</td>
</tr>
<tr>
<td>Mindfulness and Repetitive thinking</td>
<td>-0.69</td>
</tr>
</tbody>
</table>

*Note.* All significant correlations between the residuals of the VAR models are shown (*p*< 0.05). Part = participants.
**Discussion**

This study examined the temporal relationships between day-to-day changes in mindfulness, repetitive thinking, and depressive symptoms in six women with depressive symptoms participating in a mindfulness-based treatment. The results showed that changes in mindfulness preceded changes in depressive symptoms in only one participant and that changes in repetitive thinking preceded changes in depressive symptoms in two participants. For three individuals, we found that daily changes in mindfulness predicted changes in repetitive thinking the next day. We did not find evidence for reverse causality. Daily changes in depressive symptoms did not precede changes in repetitive thinking and mindfulness in any of the participants. Another consistent finding was that day-to-day changes in mindfulness, repetitive thinking, and depressive symptoms occur together, as all participants showed moderate to strong concurrent associations between the variables.

The few lagged associations in the hypothesized direction suggest that temporal precedence of daily mindfulness and repetitive thinking may take place in some but not all individuals. This corresponds with the notion that psychological change processes may differ across individuals (Molenaar, 2004; Rosmalen et al., 2012). Another reason for the few lagged associations may be the chosen time interval between the measurements. Daily assessments were performed once a day at the end of the day. An interval of one day may be too long to find a lagged effect if the effects are established very rapidly or taper off after a night of sleep. The strong within-day associations found in the current study might indeed indicate that change processes operate fast during mindfulness-based treatment. Some of the study participants reported at the end of the study that their level of depressive symptoms was not constant during the day, which corresponds with results from other studies showing fluctuations in affect over the course of a day (Peeters, Berkhof, Delespaul, Rottenberg, & Nicolson, 2006). We may not have captured these dynamic changes over the course of the day with our daily assessments.

Another possibility is that cognitive processes and affect are too much intertwined to unravel the temporal chain of events in an observational study using self-report measures. For example, Clark and Teasdale (1982) showed that negative memories are more accessible during depressed parts of the day than during less depressed parts of the day. The daily self-reports of mindlessness, repetitive thought, and depressive symptoms may have been induced by depressive symptoms at the end of the day (Ebner-Priemer et al., 2006). This may as well explain the strong
concurrent associations among the study participants. In future research, it may therefore be valuable to include measures of another nature, such as behavioral measures or physiological indicators, to ensure that process and outcome variables are not too closely related (Stanton, Luecken, MacKinnon, & Thompson, 2012).

The study findings do not undermine the assumed change processes underlying mindfulness-based treatments. For none of the participants we found a reverse temporal order of change, with decreases in depressive symptoms preceding changes in the other variables. Such a finding would have challenged existing theories of therapeutic change in mindfulness-based treatments.

The present study shows that the adopted replicated single-subject approach is a suitable method for studying the temporal order of change in research on mechanisms. Such a design is more useful than a pre-post-treatment design because temporal precedence can only be investigated with multiple repeated measurements within individuals. Also, recall bias is reduced and ecological validity is enhanced with the use of daily measurements (aan het Rot, Hogenelst, & Schoevers, 2012). Another strength is that inferences can be made about dynamic processes that take place within individuals. The used vector autoregressive models enable a detailed examination of dynamic relationships between variables, taking into account potential bidirectional effects and feedback loops (Brandt & Williams, 2007). Group-level approaches cannot adequately account for such temporal complexity, and may obscure inter-individual heterogeneity by showing average group level effects that may only apply to a non-existing average individual (Allport, 1937).

Yet, the findings of the present study should be seen as preliminary for several reasons. This is the first time-series study on the temporal order of day-to-day changes in mindfulness, repetitive thinking, and depressive symptoms during a mindfulness-based treatment. The study focused on examining processes that really take place within individuals and focused less on finding an ‘average’ change process. The strengths of a replicated single-subject design are precision and a high internal validity, rather than the ability to draw conclusions for the population at large. The results may not generalize to others since the findings show what holds for these six individuals. Another sample of individual replications might reveal different findings as regards the lagged effects. Replication of the study in a larger sample is warranted to reveal whether the number of lagged effects found in our study is representative and if other individuals also do not show associations in the opposite direction. In addition, we cannot be sure
that the temporal relationships are induced by the mindfulness-based treatment as no control group was included. Future studies could shed further light on the whether these associations also occur outside a treatment context. This, however, does not downplay our conclusions on the observed order of changes, which was the main focus of the study. Also, increases in mindfulness are more likely to occur in the context of a mindfulness training. Another limitation may be that we used only a few items to measure the variables under study. We made a trade-off between reliability and feasibility, as it has been recommended to use very brief diary measures to reduce response bias and participant burden (Morren et al., 2009; Thiele et al., 2002) and to increase questionnaire completion rates (95% in the current study).

In sum, the findings of the study provide some insight into processes of change that can take place within individuals during mindfulness-based treatment. Change processes may occur fast as daily changes in mindfulness, repetitive thinking, and depressive symptoms seemed to go together, rather than to precede or follow one another in our sample. Mindfulness and repetitive thinking did precede depressive symptoms in some individuals, but not in all. The findings in our sample do not undermine the assumed change processes underlying mindfulness-based treatments as associations in the opposite direction were not observed. The study shows that a replicated single-subject time series approach can be a useful complement to the methods available in research on mechanisms, as it provides more insight in the temporal order of change, within-person associations, and individual differences.