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Changed dynamic symptom networks after a self-compassion training in patients with somatic symptom disorder: A multiple single-case pilot project

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ABSTRACT

Objective: Pre-to-post mean group differences of intermittently assessed generic outcome variables may not capture all relevant treatment-related changes in individual patients with somatic symptom disorder (SSD). Aim of this multiple single-case observational pilot project was to find out whether the Experience Sampling Method (ESM) and dynamic symptom networks may offer new opportunities in evaluating treatment outcomes for individual patients with SSD.

Methods: Patients with SSD ($N = 6$ in study 1, $N = 7$ in study 2) received a self-compassion training in a tertiary care mental health expert center. Using a single-case pre-post treatment observational design, intensive longitudinal data were collected with ESM. A brief questionnaire was presented via the patient's smartphone three times per day for 16 weeks before, during and after the training in study 1, and for 5 weeks before and 5 weeks after the training in study 2. Eleven questions comprised somatic symptoms, functional disability, stress, self-compassion, and acceptance of affect; three personalized questions comprised self-chosen affects and an additional symptom.

Results: Sufficient observations for means and network comparison were obtained for 11 and 10 patients, respectively. After the training, self-compassion was significantly increased in 10 patients, functional disability, stress and affect improved in 6 patients, and (although not a treatment goal) somatic symptoms decreased in 6 patients. Dynamic symptom networks significantly changed in 5 patients.

Conclusion: Patient-specific changes in means and dynamic symptom networks were observed after self-compassion training. In future clinical trials, single-case ESM may offer new opportunities to evaluate treatment outcomes in patients with SSD.

1. Introduction

Patients with somatic symptom disorder (SSD) are characterized by one or more somatic symptoms that are distressing and/or result in significant disruption in daily life, as well as excessive thoughts, feelings and behaviors related to these somatic symptoms or associated health concerns [1]. To be diagnosed with SSD, the individual must be persistently symptomatic (typically at least for 6 months). A bio-psychosocial stepped-care treatment model integrating somatic as well as psychosocial determinants of distress and therapeutic factors is recommended [2]. A subgroup of these patients, severely and persistently suffering from multiple somatic symptoms, functional disability, and comorbid mental disorders (such as personality disorders) needs treatment in tertiary care mental health expert centers. Although intensive multidisciplinary treatment for these patients is effective, treatment effects are usually only small to moderate [3,4].

An explanation for these modest treatment effects may be that group-averaged effects based on intermittently assessed generic outcome variables do not adequately reflect improvements for individual patients. This view is supported by large interindividual differences found in

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previous effect studies [3–6] as well as by large variety in importance attached by patients to diverse treatment outcomes [7]. Particularly patients treated in tertiary care mental health expert centers may require individual treatment goals (precision medicine), because they did not attain acceptable outcomes in primary of secondary care. An idiographic approach, with multiple single-case effect studies that allows for individual outcome measures, may show larger (individual) treatment effects. Moreover, treatment of SSD is often not focused on symptom reduction, but on skills to function better and to cope with persistent symptoms or functional disability [8]. Thus, because treatment goals often differ between patients, individual outcome variables ought to differ as well in effect studies.

Symptoms generally fluctuate over time (within and between days). Moreover, the interrelationships between symptoms, symptom evoking or perpetuating factors, and symptom consequences may not be contemporaneous but time-delayed. Thus, perceiving of and coping with the eb and flow of symptoms in daily life is a *dynamic* behavioral process. Dynamic longitudinal relationships between symptoms and other variables are considered potentially of clinical relevance for treatment and assessment, and several research groups have already highlighted or demonstrated the importance of personalized dynamic network modelling (network analysis) in psychopathology [9–14]. A treatment-related change in dynamic relationships in individual patients may thus better reflect the core aim of precision medicine in psychotherapy than a limited focus on a change in the mean level of symptoms. Such a change may demonstrate clinically meaningful additional effects, that can be independent of a change in the mean level of symptoms. Such dynamic relationships, however, are hard to assess with intermittently completed traditional retrospective questionnaires. Instead, a treatment evaluation methodology is needed that makes it possible to assess individual dynamic relationships between fluctuations in symptoms and other variables assessed (i.e., single-case dynamic symptom networks). To summarize, for a more comprehensive evaluation of treatment effects, these effects should be studied on the level of the individual patient, with a focus on a reduction of symptoms or improvement of individually chosen main goals, and with a focus on a change in the dynamic relationships between symptoms and other variables.

To identify dynamic symptom networks in individual patients, single-case studies need a method that collects intensive longitudinal data (i.e., data collection with short time intervals). The Experience Sampling Method (ESM, also known as Ecological Momentary Assessment) is a structured diary technique that yields ecological valid data of life as it is lived on the spot [9,15,16]. An application installed on the patient' smartphone can be used for prompting a patient, multiple times a day, to complete a patient-tailored brief questionnaire. ESM can be used to study pre-to-post treatment reduction of symptoms on an individual level, using a combination of predetermined and personalized items. Previous ESM studies in patients with SSD and related syndromes also examined within-subject relationships between fluctuations in symptoms and symptom evoking factors, for example in the day-to-day concurrency between fluctuations in somatic symptoms and mood [17,18]. A next step is to combine ESM with novel more complex statistical analyses to examine changes in the dynamics of processes as they unfold within individuals over time. Knowledge about pre-to-post treatment changes in dynamic symptom networks reflecting dynamic interrelationships between fluctuations in symptoms and other variables in individual patients with SSD, would give insight into mechanisms of change.

The current observational pilot project examined individual changes in mean scores and dynamic symptom networks after a self-compassion training. Self-compassion is a resilience factor that is thought to help a person during times of stress, pain and failure [19,20]. Low self-compassion is associated with reduced physical and psychological well-being in general [21]. Patients with SSD have lower levels of self-compassion than the general population [22]. Low self-compassion is also associated with more somatic symptoms and lower health-related quality of life, both in the patient group with SSD and a matched control group [22]. Especially Paul Gilbert [23] emphasized the potential of Compassion-Focused Therapy (CFT) to offset threats of somatic symptoms, stress, and other adversities that may hamper people with SSD. CFT develops people's capacity to (mindfully) access, tolerate, and direct affiliative motives and emotions, for themselves and others, and cultivate inner compassion as a way for organizing their brain in pro-social and mentally healthy ways. Thus, strengthening self-compassion is assumed to buffer associations between stress or other threats and the intensity of somatic symptoms in these patients. In this observational ESM pilot project, patient-specific changes after a self-compassion training in the mean levels and in the dynamic (i.e., autoregressive, cross-lagged, and contemporaneous) associations between fluctuations in self-compassion and fluctuations in stress, affect and somatic symptoms were examined.

ESM and dynamic network analysis are relatively new methods without validated methodological guidelines and guidelines for use in clinical practice. The aim of the current observational pilot project was to find out whether ESM and dynamic network analysis may offer new opportunities in evaluating individual treatment outcomes in patients diagnosed with SSD who were treated in a tertiary care mental health expert center. Two (multiple) single-case observational pilot studies were performed. Brief and personalized ESM questionnaires assessed self-compassion as the primary outcome, and somatic symptoms, functional disability, stress, positive and negative affect, and acceptance of affect as secondary outcomes. For the dynamic symptom networks, the primary focus was on the dynamic relationships between self-compassion, stress, and somatic symptoms. In both observational studies, it was explored whether meaningful patient-specific changes in dynamic symptom networks could be demonstrated. Applying this method in future clinical trials may disclose causal effects of self-compassion training in individual SSD patients, both on mean symptom levels and on dynamic symptom networks.

2. Method

2.1. Participants

Patients were treated at the tertiary care mental health expert center Altrecht Psychosomatic Medicine Zeist, The Netherlands. Inclusion criteria for the self-compassion training were being diagnosed with SSD, having completed a preceding mindfulness training (once a week over the course of 8 weeks), being assessed by therapists as low on self-compassion skills and eligible for the self-compassion training, and patient's willingness to follow it. Exclusion criteria for the observational study were not being in possession of a smartphone or not wanting to participate in the study and complete the ESM questionnaires on the smartphone. In pilot study 1 (Sept - Dec 2018), eight patients (seven female and one male) participated. One participant withdrew on the first day of the training, another dropped out of the study after three sessions. The mean age of the remaining sample ($n = 6$, one male) was 49.0 ($SD = 12.6$) years. In pilot study 2 (Sept 2019 - Feb 2020), a total of eight patients (seven female and one male) with SSD participated. One participant withdrew during the first assessment period. The mean age of the remaining sample ($n = 7$, all female) was 39.9 ($SD = 12.0$) years.

2.2. Self-compassion training

The mindful self-compassion training was part of the program in our treatment center for several years. It is a group-based training program to provide participants with a variety of skills to increase self-compassion. The training is based on Mindfulness-Based Compassionate Living (MBCL) [24] and it has common grounds with the Mindful Self-compassion Program (MSP) [25]. The training was developed as a sequel for people who had completed a mindfulness-based stress reduction training. The program focused on helping participants to develop self-compassion through psychoeducation, mindfulness, meditation, experiential exercises, and home assignments to incorporate self-compassion practices in daily life. The training was supervised by two group therapists. A full description of the training has been given elsewhere [26]. In observational study 1 (2018), participants met once a week for two and a half hours over the course of 8 weeks. In observational study 2 (2019), participants met for two and a half hours once every two weeks in eight sessions spread over 16 weeks.

2.3. Procedure and ESM-questionnaire

The study protocols for both pilot studies were approved by the Institutional Review Board of Altrecht (CWO-nr 1613: 22-06-2018/13-06-2019) and participants signed informed-consent forms before inclusion in the study. In both studies, patients completed a baseline questionnaire (5 items) once at the start of the study, and a brief ESM-questionnaire three times per day for several weeks. ESM was performed on the smartphone using the Ethica app (www.ethicadata.com). Notifications were pushed three times a day to complete the next ESM-questionnaire, and a reminder in case it was not completed after 20 min. Expire time was three hours.

The baseline questionnaire consisted of 2 questions to select a self-chosen positive and negative affect ESM-questionnaire item, 2 question to add a self-chosen symptom item, and 1 question to personalize ESM notifications to three convenient times per day with five hours interval (e.g., 12:00, 17:00, 22:00).

The brief ESM-questionnaire consisted of 14 items all referring to the previous part of the day (e.g.: “Last part of the day I was stressed”). Visual Analogue Scales (VAS; internally coded as [0−100]) anchored (for example) at the left by “not at all” and right by “very much” were used as response format. The items comprised severity of somatic symptoms, functional disability due to somatic symptoms, stress, a self-chosen negative affect item, acceptance of negative affect, a self-chosen positive affect item, acceptance of positive affect, (optionally) a self-chosen symptom, and self-compassion. Self-compassion was assessed by six items derived from the Self-Compassion Scale (SCS) [27] (self-kindness, self-judgement, common humanity, isolation, mindfulness, and over-identification) which were (after recoding negative items) averaged to obtain one self-compassion score. A selection of six items based on the SCS was made to limit the burden for and dropout of participants. The ESM-questionnaire is provided as supplementary material (paragraph 2.3).

2.4. Design and data analysis for both studies

Both pilot studies were purely observational, that is, observations were added to an ongoing training. It was not a clinical trial and patients were not prospectively assigned to the training (or a modified version of it) to study health outcomes. The observational study was a multiple single-case pre-post treatment observational ESM-design, combining an existing training with collection of intensive longitudinal (questionnaire) data. Data were analyzed separately for each participant. The rationale for the chosen design and methods of (dynamic) time series analysis is provided as supplementary material, paragraphs 2–6.

In study 1, ESM continued before, during and after the training (i.e., for 16 weeks). Testing pre-to-post treatment differences in the means was done using the assessments during baseline (four weeks) and during follow-up (four weeks). In study 2, ESM was performed twice: the five weeks before and the five weeks after the training, and not during the training. Testing pre-to-post treatment differences in the means could therefore make use of all observations. Study 1 thus also examined the process of change during the training, while study 2 examined stationary pre- and post-treatment states. Single-case pre-post effect sizes, similar to group-level Cohen’s d, were computed; in autocorrelated time series d-values <1 are interpreted as small, 1.00–2.49 as medium and ≥ 2.50 as large [28]. Changes in the means were tested with a single-case one-sided permutation test that correct for dependency of the observations and a baseline trend (supplementary material, paragraph 3).

Table 1
Demographics, number of observations and compliance per patient.

—	Demographics			Number of observations			Compliance
	Gender	Age	SCS	Pre (n)	Training (n)	Post (n)	(%)
1A	F	34	90	70	105	37	54.0
1B	F	32	82	61	109	43	68.7
1C	F	59	76	67	81	0	71.6*
1D	F	56	76	77	124	0	61.8*
1E	M	54	74	75	142	70	85.1
1F	F	59	51	80	159	72	98.1
2A	F	27	69	93	–	88	86.2
2B	F	30	85	72	–	67	65.9
2C	F	51	50	107	–	103	98.6
2D	F	44	89	99	–	99	96.1
2E	M	30	77	31	–	15	34.6
2F	F	59	90	108	–	99	97.6
2G	F	38	83	68	–	67	72.2

Patients 1A-1F participated in study 1, patients 2A-2G participated in study 2; F = female, M = male; SCS = initial scores on the Self Compassion Scale; Pre = assessment period before training, Training = assessment period during training, Post = assessment period after training; Compliance is defined as the percentage of delivered notifications that were followed by completing the ESM-questionnaire; * In the compliance percentage, the post-training period was excluded for these patients.

Individual dynamic symptom networks were computed using a flexible latent variable modelling framework with Bayesian analysis, referred to as Dynamic Structural Equation Modelling (DSEM) [29] with a five hour time interval. DSEM can deal with several statistical challenges such as imputation of missing values, standardization of the within-subject ϕ estimates, and observations with unequal spaced time-intervals. A corresponding modelling framework was used for residuals correlated across time, referred to as Residual DSEM (RDSEM) [30]. We applied single-subject RDSEM, using MPLUS version 8.2, to control for circadian cycle, weekend-effects, and low-frequency trends derived from the corresponding observed variables. This approach reduces often overlooked biases in our model [31]. In this approach, latent variables are created, but they are not based on multiple indicators, rather, these latent variables are residuals. A residual signal may be considered as a filtered signal, for example, as a residual without its own low-frequency trend. Then a VAR1 model [32] is fitted on these residuals yielding standardized estimates for the autoregressive, cross-lagged, and (residual) contemporaneous associations, which is a dynamic network interpretation comparable to earlier work [11], but more sophisticated. The pre-treatment and post-treatment observations were included as separate variables in the model, with missing values for the non-corresponding time-segment. In this way, the pre- and post-treatment networks could be analyzed in a single RDSEM-model, allowing to compute and test pre-to-post differences of all estimates (supplementary material, paragraphs 4–6). The minimum number of observations required to compute a reliable network was set to 60.

For study 1, individual dynamic symptom network analysis combined the observations for a participant during baseline and training part 1, and the observations during training part 2 and follow-up. This was needed to obtain enough observations to compute reliable networks. Notify that our RDSEM-model performs a correction for a gradual change (i.e., trend) during the treatment. For study 2, the baseline and follow-up observations each provided sufficient data to perform network analysis. Pre-to-post treatment differences in the individual dynamic symptom networks examined the networks of self-compassion, stress, and symptoms.

To summarize, the individual dynamic symptom networks in the current pilot project show the lagged and contemporaneous relationships between time series (i.e., fluctuations over time in the ESM-

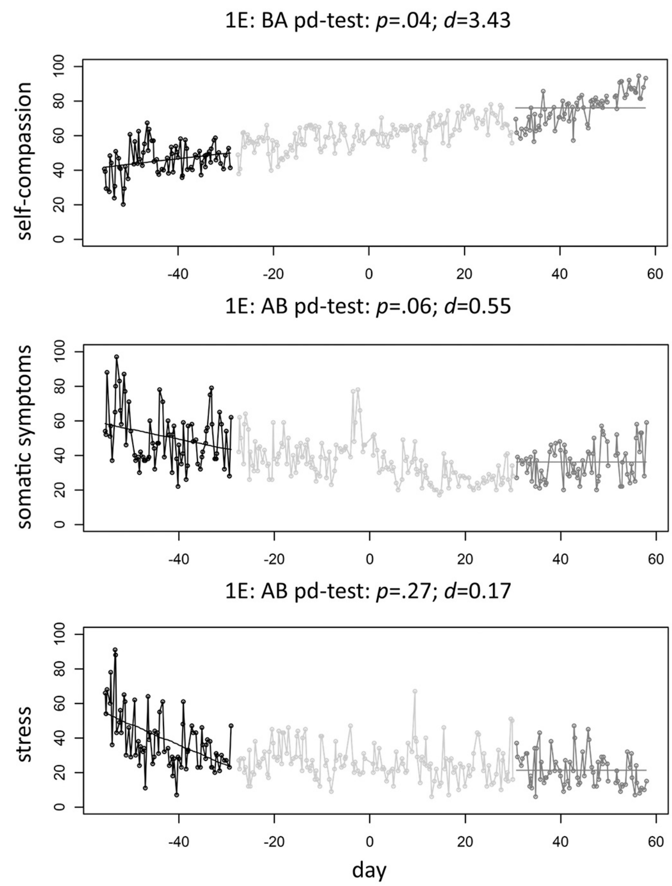

Fig. 1. Experience Sampling Method (ESM) data for subject 1E of pilot study 1. Day 0 was halfway the training. The pre (left side, black) and post (right side, dark gray) training values were used in the statistical permutation distancing tests (AB or BA pd-test). In this test, the mean pre-training value is corrected for the trend (A depicted as the dashed line on the left) and the trend-corrected mean (the last score of the dashed line on the left) is compared to the mean post-training value (B depicted as the horizontal dashed line on the right); *d* = pre-post training single-case effect size.

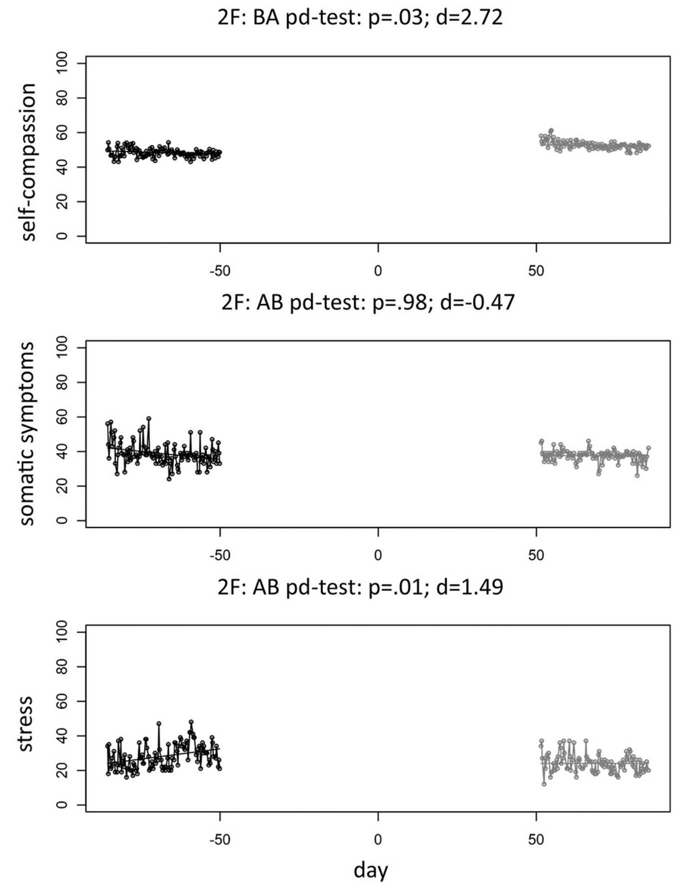

Fig. 2. Experience Sampling Method (ESM) data for patient 2F of pilot study 2. In this study data collection stopped during the training and started again afterwards. The pre (left side, black) and post (right side, dark gray) training values were used in the statistical permutation distancing tests (AB or BA pd-test). In this test, the mean pre-training value is corrected for the trend (A depicted as the dashed line on the left) and the trend-corrected mean (the last score of the dashed line on the left) is compared to the mean post-training value (B depicted as the horizontal dashed line on the right); *d* = pre-post training single-case effect size.

variables). A significant lagged positive cross-relationship from 'stress' [first] to 'severity of somatic symptoms' [next] can, for example, be interpreted as that an increase in stress precedes an increase in somatic symptoms 5 h later (i.e., the time interval was set to 5 h). A significant (residual) contemporaneous positive relationship between stress [next] and symptoms [next] can be interpreted as co-occurring increases in stress and somatic symptoms without delay.

3. Results

3.1. Demographics and compliance

Table 1 presents demographics and the number of ESM observations per patient. Sufficient single-case observations to reliably test pre versus post training differences in the means were available for four patients in study 1 (patients 1C and 1D did not complete the ESM-questionnaire after the training) and for all seven patients in study 2. Sufficient single-case observations to reliably test differences in dynamic networks (i.e., at least 60) were available for the same four patients in study 1 (notify that for study 1 pre-networks were computed for the observations till halfway the training and post-networks for the observations from halfway the training) and for six patients in study 2 (the compliance of patient 2E was too low). The overall response to notifications on the smartphone was sufficient; the mean compliance computed as the ratio of surveys completed divided by the number of notifications delivered on the smartphone was 77.9% (*SD* 20.9).

3.2. Results for individual pre-to-post training differences in the mean levels

Figs. 1 and 2 display individual results of a patient in study 1 and a patient in study 2 for self-compassion, somatic symptoms, and stress. The individual results for all outcome variables and all patients are provided as supplementary material (supplementary material figures). Table 2 presents the number of significant results and the mean effect sizes for all outcome variables across patients.

3.3. Results for the individual dynamic symptom networks

The second focus of the current pilot project was on the individual pre- and post-treatment dynamic symptom networks combining self-compassion, somatic symptoms, and stress, and to examine pre-to-post training changes in these networks. Figs. 3 and 4 display the results for two patients (patient 1E and 2F) corresponding with the data presented in respectively Figs. 1 and 2. To reduce statistical Type II errors, only network estimates (within-subject standardized ϕ values) were selected that were both below a threshold for significance ($p < .025$, two-sided) and above a threshold chosen for a clinically relevant (meaningful) effect (estimate >0.1). The dynamic symptom networks

Table 2
Number of patients with significant pre-to-post training differences in the means, and mean effect sizes across patients at all nine outcome variables.

Outcome	Number patients with $p < .05$ Study 1 (n)	Study 2 (n)	Overall (n)	Effect size (d) Study 1 M (SD)	Study 2 M (SD)	Overall M (SD)
self-compassion ↑	4 of 4	6 of 7	10 of 11	3.75 (4.28)	1.49 (1.09)	2.40 (2.85)
somatic symptoms ↓	2 of 4	4 of 7	6 of 11	0.34 (0.44)	0.43 (0.50)	0.40 (0.45)
functional disability ↓	2 of 4	4 of 7	6 of 11	0.34 (0.43)	0.33 (0.58)	0.34 (0.50)
stress ↓	2 of 4	4 of 7	6 of 11	0.79 (0.86)	0.35 (0.73)	0.53 (0.77)
self-chosen negative affect ↓	2 of 4	2 of 7	4 of 11	0.63 (0.57)	0.16 (0.43)	0.34 (0.52)
acceptance negative affect ↑	4 of 4	2 of 7	6 of 11	3.78 (3.37)	1.27 (1.32)	2.27 (2.54)
self-chosen positive affect ↑	3 of 3*	2 of 7	5 of 10	1.64 (0.99)	0.46 (0.65)	0.85 (0.93)
acceptance positive affect ↑	3 of 4	4 of 7	7 of 11	3.24 (3.33)	1.54 (0.95)	2.22 (2.23)
self-chosen symptom ↓	2 of 4	1 of 7	3 of 11	0.52 (0.64)	0.08 (0.39)	0.25 (0.52)

M = mean; SD = standard deviation across patients; d = single-case pre-post effect size; * One participant did not select a self-chosen positive affect; ↓ = reduced after the training, ↑ = increased after the training.

for all patients are provided as supplementary material (supplementary material figures).

Fig. 3 (patient 1E) shows, for example, that increased self-compassion preceded reduced stress before training (standardized estimate −0.35), and that (both networks) increased self-compassion was contemporaneously related to less somatic symptoms (−0.22, −0.39). None of the differences between networks were significant for this patient. Fig. 4 (patient 2F) shows, for example, that before training stress preceded increased somatic symptoms (0.28), and that increased self-compassion was contemporaneously related to less somatic symptoms (−0.32). Significant differences between both networks were only found for this contemporaneous association ($p < .001$). See the discussion for how these results, combined with results on a change in the mean levels, may be clinically interpreted.

Table 3 summarizes the dynamic symptom network results combining self-compassion, somatic symptoms, and stress across all patients per pilot study. The number of patients with a significant pre-to-post training change for the specific estimate was added. As expected, network results varied across patients. A significant (cross-lagged or contemporaneous) association between symptoms and stress was always positive (10 out of 10), a significant association between symptoms and self-compassion was almost always negative (17 out of 18), and a significant association between self-compassion and stress was always negative (17 out of 17). A significant difference between the pre- and post-treatment networks was found in 5 out of 10 patients.

4. Discussion

To find out whether ESM and dynamic network analysis may offer new opportunities in evaluating individual treatment outcomes, the first focus of the current observational pilot project was to examine

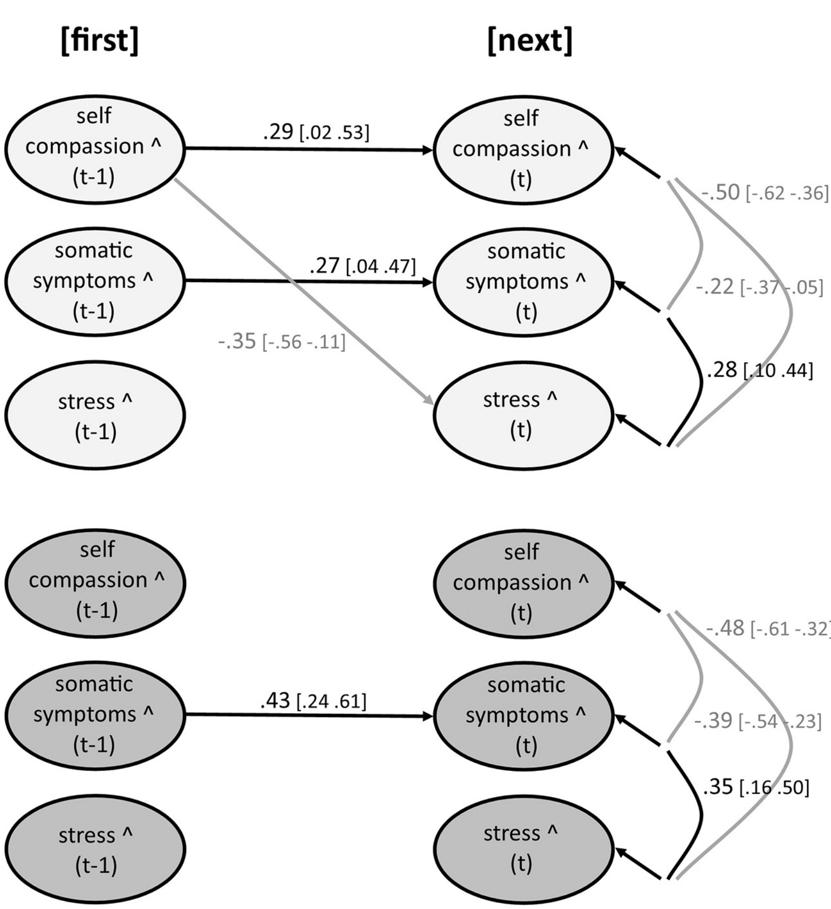

Fig. 3. Pre (top) and post (bottom) training dynamic network results for patient 1E (of pilot study 1). The networks were computed for baseline and training part 1 (upper network) versus for training part 2 and follow-up (lower network) data; respectively the negative versus positive day numbers in Fig. 1. Estimates [95% CI] were standardized; [first] and [next] refer to preceding (t-1) and following (t) part of the day; ˆ = residual latent variable corrected for circadian cycle, weekend, and low-frequency trends.

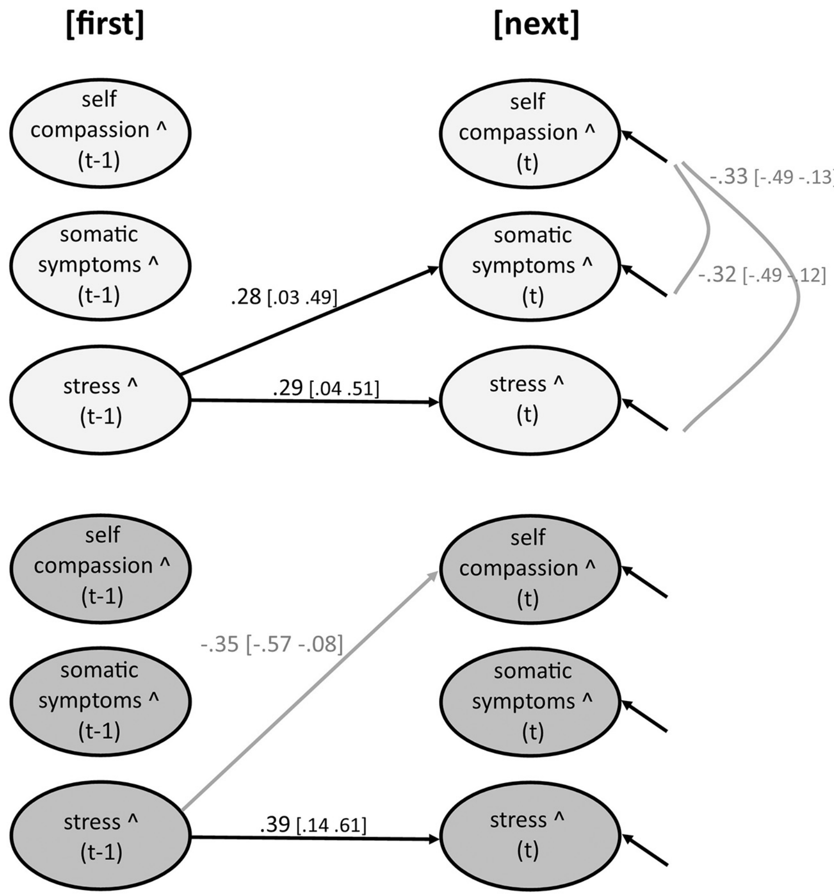

Fig. 4. Pre and post training dynamic network results for patient 2F (of pilot study 2). The networks were computed for baseline (top side network) and follow-up (bottom side network) data; respectively the negative versus positive day numbers in Fig. 2. Estimates [95% CI] were standardized; [first] and [next] refer to preceding (t-1) and following (t) part of the day; ^ = residual latent variable corrected for circadian cycle, weekend, and low-frequency trends.

individual changes in mean scores after a self-compassion training. Results indicated positive changes after the self-compassion training for most patients with SSD: improvements after the training were observed for self-compassion, acceptance of negative affect, acceptance of positive affect, stress, and functional disability. A reduction in somatic symptoms was (although not a treatment goal) found in 6 out of 11 patients. This reduction is considered a secondary outcome related to improvements in self-compassion, stress and (acceptance of) affect, resulting from the training program. These findings correspond with results of previous studies, that demonstrated positive outcomes of compassion-based interventions [25,33,34], and tentatively indicate that they, if confirmed in a clinical experimental design, may be extended to patients with SSD. As a second focus, we examined whether a change in dynamic symptom networks may increase insight into individual improvements, based on the assumption that changed dynamic patterns of (time-lagged or contemporaneous) concurrency could reflect therapeutic process changes. Patient-specific changes were indeed found either in mean levels or in dynamic symptom networks, or in both. Thus, single-case ESM studies combined with dynamic data analyses methods can potentially demonstrate individual improvements in the dynamics between symptoms, independently of changes in the mean levels. This is illustrated by the results found for patients 1E and 2F (Figs. 3 and 4).

4.1. Inter-individual differences

Large inter-individual differences were found in the effect-sizes of the pre-to-post training differences in mean levels (Table 2). This justifies the single-case study approach in this patient group. The largest inter-individual differences were found for increased self-compassion and increased acceptance of both positive and negative affect, reflecting the goals of the self-compassion training. The dynamic symptom network results (Table 3) were, as expected, also patient specific. However, some specific effects (i.e., the contemporaneous associations between self-compassion, somatic symptoms, and stress) were consistently found across patients, and the direction of effects when found (e.g., more self-compassion precedes less somatic symptoms) were also consistent across patients. Thus, although some dynamic symptom network results were quite common, large inter-individual differences were observed as well. A strong asset of our single-case approach is that it can identify patient-specific networks. Several influences may underlie inter-individual differences, including differences between both pilot studies in the training schedule and in the ESM design; the number of participants, however, was too low to test this.

4.2. The clinical value of dynamic symptom networks

Feedback of personal ESM results combining means and dynamic symptom networks may have clinical value for patients with SSD regarding shared decision making about the focus of therapy, as well as for evaluation of therapy. The therapist and patient can discuss the results using the graphic outputs. In evaluation of therapy, possible other contributing factors such as history, maturation and factors the patient suggests should also be explained and discussed. For patient 1E (Figs. 1 and 3), the mean level of self-compassion was larger after the training and a trend was found for less somatic symptoms. The dynamic network graphic before training suggests that self-compassion served as a buffer against moments of stress, while stress was associated with more somatic symptoms. Notify that significant pre-to-post network changes

Table 3
Number of significant (p < .025) and relevant (standardized estimate > 0.1) results across patients and number of significant pre-to-post training difference tests per dynamic symptom network estimate.

	Pre-training (n)	Post-training (n)	Pre-post difference (n)
Study 1 (4 patients)			
symptoms → self-compassion	–	–	–
symptoms → stress	–	–	–
self-compassion → symptoms	–	1 neg	–
self-compassion → stress	1 neg	–	–
stress → symptoms	1 pos	–	–
stress → self-compassion	–	1 neg	1
symptoms ↔ self-compassion	2 neg	2 neg 1 pos	2
symptoms ↔ stress	2 pos	3 pos	1
stress ↔ self-compassion	4 neg	3 neg	2
Study 2 (6 patients)			
symptoms → self-compassion	–	–	–
symptoms → stress	–	–	–
self-compassion → symptoms	2 neg	1 neg	1
self-compassion → stress	–	–	–
stress → symptoms	1 pos	–	1
stress → self-compassion	–	1 neg	1
symptoms ↔ self-compassion	6 neg	3 neg	1
symptoms ↔ stress	2 pos	1 pos	–
stress ↔ self-compassion	4 neg	3 neg	1

n = number of patients with a significant and relevant estimate for the effects mentioned (pre- and post-training columns) and number of patients with a significant pre-post training difference in this standardized ϕ estimate (last column); autoregressive effects were omitted to reduce the table size; → = cross-lagged association effect (to the next part of the day); ↔ = contemporaneous association effect (for the same part of the day); neg = negative estimate found; pos = positive estimate found.

were not found and differences between graphics should thus be discussed with hesitation. For Patient 2F (Figs. 2 and 4), the mean level of self-compassion was larger, and the mean level of stress was lower after the training. The dynamic network graphic before the training indicated that stress precedes more somatic symptoms, and self-compassion was associated with less somatic symptoms and less stress. Networks significantly differed on the negative association between self-compassion and somatic symptoms, which may be interpreted and discussed by the therapist and patient as that stress buffering became more permanent. Sharing and discussing these graphics in therapy can motivate patients to start and to continue practicing self-compassion daily. One of our patients that received personal feedback on her progress afterwards, based on a report combining the progress in the mean levels and the change in the dynamic symptom network, reported that this feedback motivated her to continue practicing the acquired self-compassion skills.

4.3. Limitations and future directions

First, the observational design is a limitation of our pilot study. We chose this design, because our exploratory project examined a new technology of which we initially wanted to test the potential validity. Because of this design, we cannot rule out that effects found were confounded by history and maturation. A Randomized Controlled Trial (RCT) or a Single-Case Experimental Design (SCED; e.g., by randomization start of the intervention across participants or alternating treatment conditions with a placebo or waiting list condition [35,36]) are considered next steps needed to demonstrate treatment outcomes with more internal validity. An experimental design can be combined with ESM, yielding an overview of multiple single-case pre-to-post treatment changes in means and dynamic networks. Secondly, findings from ESM studies with a smartphone only generalize to patients in possession of a smartphone, which was the case for all patients who were approached to participate in the current project. Thirdly, large inter-individual differences were found in the single-case effect sizes found, requiring a measure of heterogeneity. For future multiple single-case studies, an index of heterogeneity of individual effect sizes should be developed, comparable to heterogeneity across studies in a meta-analysis. Fourthly, individual pre-to-post network differences in the estimates were sometimes not significant, while comparison of the graphics suggested differences. This may either have resulted from Type II errors in the network estimates, Type I error in computing the significance of the difference, or from the thresholds for significance and clinically relevance used in the current study. Our method that includes pre-treatment and post-treatment observations as separate variables in one DSEM-model, with missing values for the non-corresponding time-segment, needs further statistical elaboration and validation (e.g., by simulation studies) to answer these issues. Finally, although multilevel modelling was not the scope of the current pilot project, using a time series model at level 1 to describe the within-person dynamic process while allowing for individual differences in the parameters of these processes at level 2 is also possible for dynamic networks [13,37], and is a statistical tool that can also be used to test pre-to-post treatment changes in dynamic symptom networks across patients. Another future direction can be found in person-tailored intervention based on ESM-results, which is, for example, currently being studied for depression [38,39].

5. Conclusions

The current observational pilot project, focusing on patients with SSD treated with a mindful self-compassion training, indicated that ecologically valid process variables assessed with ESM can be used to examine individual pre-to-post changes in means as well as in dynamic symptom networks. It is concluded that single-case ESM combined with individual dynamic symptom networks may offer new opportunities in future clinical trials to evaluate treatment outcomes in individual patients with SSD.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jpsychores.2022.110724.

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