Brief mindfulness practice modifies negative self-related thoughts, interoceptive awareness and autonomic nervous system response in recurrently depressed individuals.

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ABSTRACT

Depression is a highly prevalent and debilitating disorder characterized by depressive rumination. Depressive rumination is linked to poor recovery and increased risk of recurrence amongst those with a history of depression. Mindfulness practice is proposed to target adaptive attention regulation, breaking up ruminative processing by directing attention to the embodied experience of present-moment sensations. Yet, the cognitive, interoceptive and physiological differences between states of mindfulness practice and depressive rumination are not well understood in individuals with recurrent depression. Hence, meditation-naïve participants with recurrent depression underwent an experimental paradigm consisting of wakeful rest, and states of mindfulness meditation and ruminative processing. We assessed heart and respiration rate as well as cognitive and interoceptive experience after each state. The state manipulations showed that the mindfulness meditation was effective in reducing negative self-related thoughts, increasing body awareness and calming respiratory and cardiac response. In contrast, the rumination state led to increased negative self-related thoughts, decreased body awareness and faster respiration and heart rate. These findings support the premise that engaging in mindfulness practice may help break depressive patterns of thinking amongst individuals with recurrent depression.

INTRODUCTION

Major depressive disorder (MDD) is a highly prevalent and debilitating affective disorder and a leading cause of disability worldwide (WHO, 2020). Depression tends to follow an increasingly chronic and recurrent course. Individuals who have a history of three or more episodes of depression have a recurrence risk of 80%, and many patients do not fully recover (Fava, 2018). Consequently, optimizing preventative treatments for the recurrence of depression is crucial.

Mindfulness-based Cognitive Therapy (MBCT) is an effective treatment for the prevention of relapse and the reduction of recurrence risk amongst individuals with a history of recurrent depression (Kuyken et al., 2016). Recurrent depression is characterized by a cognitive vulnerability to relapse, meaning that negative biases and ruminative processes characteristic of previous episodes are easily activated by changes in mood, increasing the risk of relapse (Figueroa et al., 2015; Moulds et al., 2008; Segal et al., 2013b; Z. V. Segal, Williams, Teasdale, & Gemar, 1996). MBCT is proposed to facilitate adaptive attention, emotion and self-regulation skills (van der Velden et al., 2015). Specifically, participants are taught to recognize, decenter and disengage from ruminative negative thoughts, by redirecting their attention to the embodied experience of present-moment sensations, and relating to the change and flux of the present-moment experience with a non-judgmental, accepting and curious attitude (Segal et al., 2013b). Both the "*what*" (i.e. the attentional focus) and the "*how*" (i.e. the attitudinal qualities) of mindfulness practice are believed to be central therapeutic elements (R. Baer et al., 2019) in breaking depressive ruminative thought patterns (Kuyken et al., 2010).

MBCT was developed based on a theoretical model stating that the mind has multiple modes responsible for receiving and processing cognitive and affective information (Barnard & Teasdale, 1991), and that the ability to shift between different modes of processing is central for mental health (J. Mark G. Williams, 2008). Individuals vulnerable to recurrent depression are more prone to engage in and get "stuck" in a mental "doing mode" characterized by mentally trying to get away from the emotional pain (experiential avoidance) and ruminating on the symptoms of one's distress, and on its possible causes and consequences, as well as the discrepancy between ideas of current and desired states (Segal et al., 2013b; J. Mark G. Williams, 2008)). However, instead of improving mood, the ruminative problem-solving mode (i.e. engaging processes of analyzing, remembering, anticipating, comparing, and judging) combined with over-generalized and negatively biased thinking patterns tends to cause a negative spiral of negative thinking patterns, experiential avoidance and worsening symptoms of depression (J. Mark G. Williams, 2008). In contrast, the mental "being mode" of present-moment sensory awareness is proposed to be incompatible with a ruminative mode of mind and characterized by an approach-orientated attitude and metacognitive awareness (Segal et al., 2013b). Preliminary studies suggest that awareness of the body (i.e. interoceptive awareness) and self-referential thinking may represent two distinct, yet integrated aspects of the self (Lackner & Fresco, 2016), and that sensitivity to bodily stimuli and neural substrates for interoception is impaired in depression, which may play a role in the difficulty in disengaging from dysfunctional cognitive processing (Harshaw, 2015). Increasing bodily awareness during the mindfulness practice may be related to the ability to disengage from dysfunctional cognitive processing, as the act of intentionally directing attention toward present moment-to-moment experience is proposed to use much of the available attentional resources, leaving little room for ruminative processing related to depressive relapse (N. Farb et al., 2015; Segal et al., 2013b). Furthermore, the body may serve as an anchor, allowing negative thoughts that arise in the field of awareness to be seen as just thoughts, *"whereupon attention is redirected to the present moment, preventing further negative associations that might otherwise escalate into ruminative depressogenic patterns of thinking"* (Segal et al, 2013, p 55 (Segal et al., 2013b).

Research on mechanisms in MBCT for recurrent depression has predominantly focused on psychological dispositions related to mindfulness skills and rumination (Alsubaie et al., 2017). However, without an experimental design, it can be difficult to discern whether improvement in dispositional mindfulness skills and decreased trait rumination is a causal effect or a byproduct of symptom change following MBCT treatment (van der Velden et al., 2015). Despite the proposed role of the mindful and experiential "being" mode and the discrepancy-focused "doing" mode or rumination in the theoretical model, there is a lack of research that has experimentally studied how cognitive, interoceptive and physiological markers change and interact across these modes of mind. Hence, in an experimental study with 80 meditation-naïve participants with recurrent depression, we investigated how manipulations of states of rest, mindfulness and rumination affected self-related negative thoughts, body awareness and autonomic nervous system response.

METHODS

Study design and participants

To speak to how states of mindfulness practice and rumination impact self-related negative thoughts, body awareness and autonomic nervous system response amongst individuals with recurrent depression, we set up an experimental study with 80 meditation-naïve participants with recurrent depression, where we manipulated states of rest, mindfulness practice and rumination.

We recruited participants from general practices and psychiatric units in the central Denmark region, including Danish-speaking adult participants (aged 18 or older) with a) a diagnosis of recurrent major depressive disorder with or without a current episode in the mild to moderate range; b) three or more previous major depressive episodes; c) if on antidepressants, a stable dose of SSRI or SNRI medication for a minimum of 8 weeks; and excluding participants with d) psychiatric comorbidity i.e., a history of schizophrenia, schizoaffective disorder, bipolar disorder, current severe substance abuse, organic mental disorder, current/past psychosis, pervasive developmental delay, persistent antisocial behavior, persistent self-injury requiring clinical management/therapy; e) concurrent psychotherapy or previous completion of MBCT/MBSR training and/or extensive meditation experience (i.e. retreats or regular meditation practice); f) anti-psychotic medication and benzodiazepines.

All participants gave their written informed consent to participate, and the study protocol was registered at the Danish Data Protection Agency (2016-051-000001), and the original and updated study protocol approved by the regional ethics committee in the central Denmark region (ID: 1-10-72-259-16: 66534).

Measures and procedures

Participants completed cardiac (pulse photo-plethysmography) and respiratory (respiratory chest motion) measures, and experience sampling measures of body awareness and negative self-related thoughts across states of rest, mindfulness practice and rumination.

Paradigm

The paradigm consisted of four states of 5 minutes' duration in the following order: 1) resting state, 2) instructed mindfulness state, 3) resting state, and 4) instructed rumination state. These precedures are described in full elsewhere (van der Velden et al., see paper 3 in this dissertation). In brief, each state was followed by experience sampling, and heart rate and respiration rate were measured continuously throughout the paradigm. For the experience sampling we used a Visual Analogue Scale (VAS) scale, where the degree of agreement from 0-100% could be indicated by moving a cursor on

the scale with a trackball. See Appendix 1 for full list of questions. The four states consisted of the following instructions:

Resting state instructions

Before the two resting states, participants were told to relax and close their eyes.

Mindfulness meditation instructions

Participants were guided through a well-established mindfulness exercise, 'the 3-step breathing space', which was used in the MBCT program. In step 1, participants are instructed to first become aware of their thoughts, feelings and bodily sensations in the present moment. In step 2, participants are asked to direct their attention specifically to the sensation of the breath and in step 3, participants are asked to expand their awareness to the body as a whole, including how thoughts and emotions leave manifestations in the body. Throughout the breathing space exercise, participants are encouraged to embody an attitude of curiosity and experiential acceptance.

Rumination induction instructions

Participants were asked to rehearse a sad autobiographical memory and subsequently were instructed to stay with their sad mood and reflect on self-related causes and consequences of their low mood (see (Karl, Williams, Cardy, Kuyken, & Crane, 2018) for a detailed description for the paradigm). The use of a negative autobiographical memory to induce sad mood and ruminative thought patterns is a well-established method in the field (Karl et al., 2018; Segal et al., 2013b; Whitmer & Gotlib, 2013). Out of ethical considerations, it was possible for participants to opt out of the rumination condition if they felt it would be too stressful for them.

Analytical approach

To analyze the change caused by a brief guided meditation, we compared resting states before and after the brief mindfulness practice and the effect on experience sampling, respiratory rate and heart rate. To analyze how a state of mindfulness differs from a state of rumination, we contrasted the guided mindfulness state and the induced rumination state using experience sampling and physiological markers. Note that the two guided conditions were equal in length of time (5 minutes), were guided by the same narrator and both conditions asked participants to focus their attention and relate to their experiences in a particular way. The difference between these conditions was in the object of attentional focus and the attitude brought to the experience. In the mindfulness condition, participants were guided to focus on the embodied present moment experiences, including body sensations and breath movement, and to relate to their experience in a curious, non-judgmental way. In contrast, during the rumination condition, participants were asked to focus their attention on a negative autobiographical memory related to a depressive episode and were guided to reflect upon how this autobiographical memory related to themselves.

Heart rate, respiration rate and heart rate variability

We measured heart rate and respiration rate across the described paradigm. Heart rate was measured with pulse photo-plethysmography (PPG) by applying a pulse oximeter. Respiration rate measures were obtained from the respiratory chest motion with a chest belt. The pulse and respiration measures were digitized at a sampling rate of 400 Hz. After recording, PPG signals were filtered with a passband filter between 2-10 Hz, the respiration signals with a passband filter between 1-5 Hz. Subsequently, all PPG and respiration signals were visually inspected for artifacts. PPG signals were

converted to (normal-to-normal) NN heartbeat intervals with the RRest Toolbox v. 3.0 for MATLAB (Charlton et al., 2017)). We computed heart rate variability using the standard deviation of normal-to normal heart beat intervals (SDNN) in milliseconds. Respiration rate was extracted from the respiration signal with the BreathMetrics Toolbox v. 2.0 for MATLAB (Noto, Zhou, Schuele, Templer, & Zelano, 2018). We examined whether the states of rest, mindfulness practice and rumination impacted the respiration, heart rate and heart rate variability with one-way ANOVAs of the different states (i.e. Resting State 1, Mindfulness, Resting State 2, Rumination). Post hoc comparisons were conducted with paired t-tests. Greenhouse-Geisser corrections were applied where relevant.

RESULTS

We recruited 80 patients, of which 75 participants completed the experimental design. Of these 58 completed the rumination condition which was voluntary for ethical reasons. The participants who did not take part in the rumination condition (N=20) were similar except for higher depressive symptoms (see appendix). See table 1 for demographic and clinical characteristics.

Physiological noise correction and exclusion

Three participants from the first recording and eight participants from the follow-up recording were excluded from heart rate and heart rate variability analysis due to excessive noise. Outlier NN intervals exceeding ±2 standard deviations due to noise were excluded. Ten subjects in the first recording and 17 subjects in the follow-up showing noisy PPG signals were successfully corrected by rejecting NN intervals exceeding ±0.5 standard deviation. On average 3.3% (0.2-10%) of the NN intervals were rejected per participant. After visual inspection two participants from the first recording and six participants from the follow-up recording were excluded from further respiration rate analysis due to excessive noise. As with the NN intervals, respiration intervals exceeding ±2 standard deviations were excluded. On average 4.4% (0-11.5%) of the respiration intervals were rejected per participant.

Effects of state manipulations

To understand how states of mindfulness practice and rumination impact self-related negative thoughts, body awareness and autonomic nervous system response amongst individuals with recurrent depression, we examined the effect of the state manipulations (i.e. resting state, mindfulness state, resting state and rumination state). One-way ANOVAs revealed a significant effect of the states on the respiration rate (RR), $F(2.33,97.76)=22.32$, $p<.001$, $\eta_p^2=.35$, heart rate (HR), $F(2.04,79.59)=12.39$, $p<.001$, $\eta_p^2=.24$, negative self-related thoughts, $F(3,138)=93.35$, $p<.001$, $\eta_p^2=.67$, and body awareness, $F(3,138)=62.29$, $p<.001$, $\eta_p^2=.58$[1]. T-tests confirmed the hypotheses that the short mindfulness induction led to slower heart and respiration rate, reduced negative self-related thoughts and increased body awareness , whereas the rumination induction led to faster respiration, increased heart rate and negative self-related thoughts and decreased body awareness (see figures 1a and 1b). For heart rate variability, the difference between state effects approached significance (with Greenhouse-Geisser correction): $F(2.4,133.6)=2.46$, $p=.065$, $h^2=04$.

When we contrasted the mindfulness state and the rumination state we found that prevalence of self-reported body awareness was more than twice as high during the mindfulness state (Mean 86.47 (SD 12.13)) than during rumination (Mean 40.21 (SD 32.90)), whereas the prevalence of self-related

[1] The experience sampling data was not normally distributed, but ANOVAs are normally robust if the sample size is not small. However, we also did a sensitivity test with non-parametric t-tests and obtained the same effects.

negative thoughts was more than 3 times as high during rumination (Mean 69.98 (SD 27.97)) than during mindfulness (Mean 18.21 (SD 21.40)) (see table 2).

Table 1: Sample Characteristics

Sample characteristics	Sample N=80
Sociodemographic characteristics	N=76
Age	43.93 (13.41)
Gender (Female/Male)	58/20 (71%)
Educational level	
Low (<2 years further education)	18 (22%)
Medium (2-4 years further education)	48 (59%)
High (>5 years further education)	14 (17%)
Marital status	
Married/cohabiting	65 (85%)
Single/not cohabiting	11 (15%)
Occupational status	
Employed	38 (49%)
Unemployed/benefits	10 (13%)
Student	4 (5%)
Retired	11 (14%)
Other	14 (17%)
Clinical Characteristics	N=78
Symptomatic (QIDS>5)	68 (81%)
Antidepressant usage	64/14 (82%)
Childhood Trauma	58.85 (6.21) N=68
Previous episodes of depression	3.89 (1.40) N=64

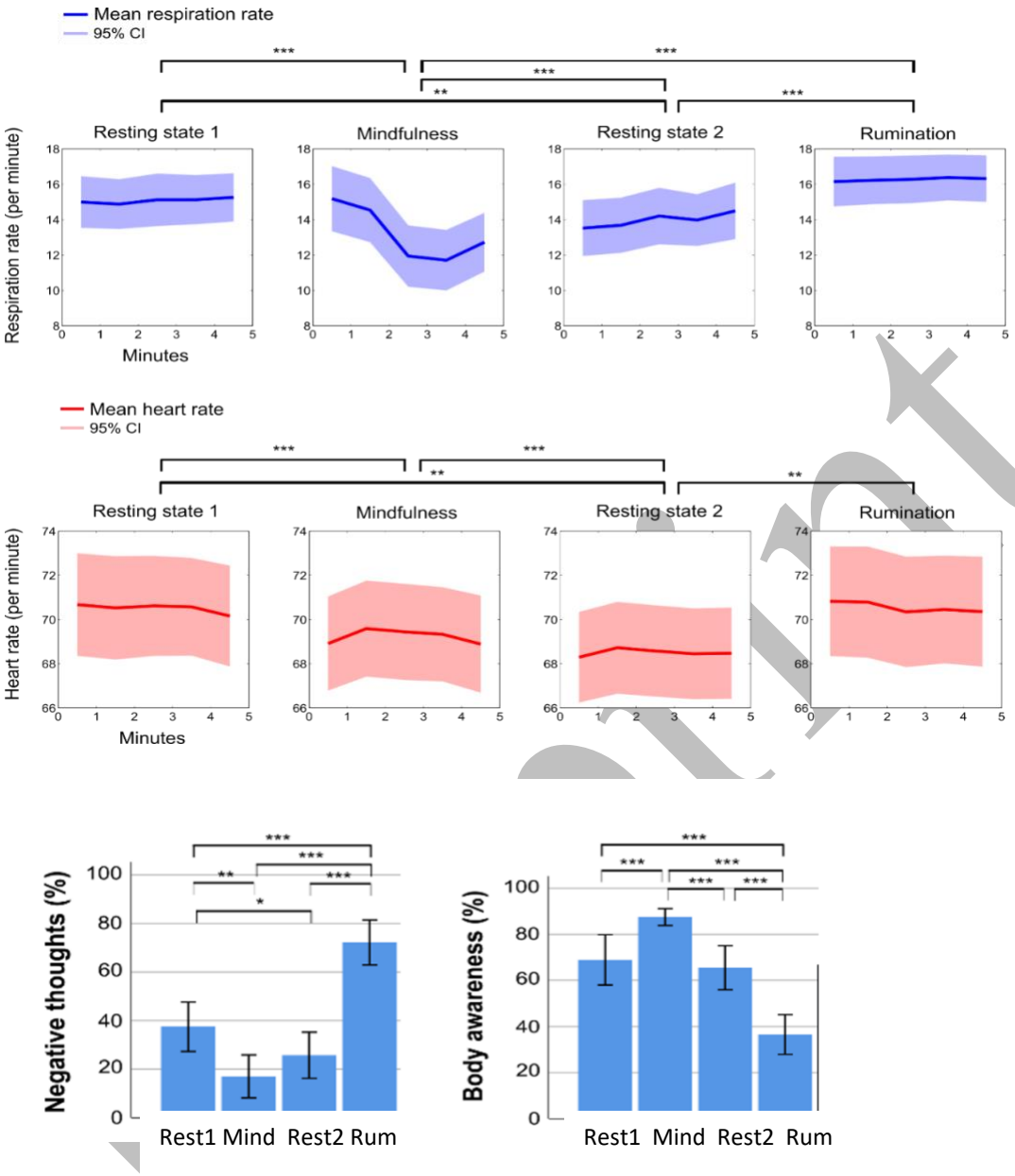

Figure 1: State effects of resting states, mindfulness practice and rumination induction on respiration rate, heart rate, negative self-related thoughts and body awareness. State effects on self-reported prevalence of negative self-related thoughts and awareness of the body using Vas-scales from 0-100% agreement with mean agreement and 95% CI. *: p<0.05, **: p<0.01, ***: p<0.001.[2] Rest1= resting state 1; Mind=mindfulness state; Rest2= resting state 2; Rum= rumination state.

Table 2: State effects on negative self-related thoughts, body awareness, respiration rate, and heart rate

Negative self-related thoughts (VAS %)					**Body awareness (VAS %)**				
Comparison	M_{diff}	**95% CI**	***P***	d_z	**Comparison**	M_{diff}	**95% CI**	***P***	d_z

[2] Note the minute-wise means differ from the total means across the five minutes applied in the statistical analyses. Additional cases needed to be excluded where no data was available at each minute after the pre-processing.

Mind Rest1	-11.3	[-17.9, -4.7]	.001**	-0.50	Mind Rest1	+18.2	[12.4, 23.9]	<.001***	0.92
Mind.Rest2	-4.6	[-10.3, 1.1]	.111	-0.23	Mind Rest.2	+16.5	[11.3, 21.7]	<.001***	0.92
Mind Rum	-52.6	[-60.5, -44.8]	<.001***	-1.94	Mind Rum	+43.8	[37.3, 50.4]	<.001***	1.94
Rest2 Rest1	-6.7	[-13.3, -0.2]	.045*	-0.3	Rest2 Rest1	+1.6	[-5.2, 8.6]	.634	0.07
Rum Rest1	+41.3	[33.7, 50.0]	<.001***	1.57	Rum Rest1	-25.7	[-33.1, -18.3]	<.001***	-1.01
Rum Rest2	+48.1	[40.1, 56.0]	<.001***	1.75	Rum Rest2	-27.3	[-34.4, -20.2]	<.001***	-1.12
Respiration rate (per minute)					**Heart rate (per minute)**				
Comparison	***M*$_{diff}$**	**95% CI**	***P***	***d*$_z$**	**Comparison**	***M*$_{diff}$**	**95% CI**	***P***	***d*$_z$**
Mind Rest1	-2.0	[-2.6, -1.4]	<.001***	-1.03	Mind Rest.1	-1.3	[-1.9, -0.8]	<.001***	-0.83
Mind Rest2	-1.1	[-1.6, -0.6]	<.001***	-0.68	Mind Rest.2	+0.7	[1.1, 0.2]	.002**	0.55
Mind Rum	-2.6	[-3.3, -1.9]	<.001***	-1.08	Mind Rum	-0.5	[-1.3, 0.2]	.187	-0.23
Rest2 Rest1	-0.9	[-1.6, -0.6]	.006**	-0.45	Rest2 Rest1	-2.0	[-2.6, -1.4]	<.001***	-1.03
Rum Rest1	+0.5	[-0.3, 1.4]	.193	0.19	Rum Rest1	-0.8	[-1.7, 0.1]	.080	-0.26
Rum Rest2	+1.5	[0.8, 2.2]	<.001***	0.63	Rum Rest.2	+1.2	[0.4, 2.0]	.003**	0.50

Table 2 Caption: Effects of the different states on negative self-related thoughts, body awareness, respiration rate, and heart rate at baseline. For each measure the six possible two-tailed pairwise comparisons between the states are shown. Body Awareness: Participants were asked about how aware they were of their body during each state 'I was aware of my body' (0-100 Vas scale with 100 being 100% aware and 0 being 0% aware. Negative self-related thoughts: Participants were asked about the extent to which they experienced negative self-related thoughts ' experienced negative thoughts about myself' during each state (0-100 Vas scale with 100 indicating 100% of the time and 0 indicating 0%). Mdiff (mean difference). dz = Cohen d (standardized). CI= 95% confidence intervals. P= pp value at *p<0.05, **p<0.01, ***p<0.001. Rest1= resting state 1; Mind=mindfulness state; Rest2= resting state 2; Rum= rumination state.

DISCUSSION

MBCT is an effective treatment amongst individuals with recurrent depression (Kuyken et al., 2016). However, it is not clear exactly how MBCT, a complex and multifaceted intervention, brings about clinical change. Mindfulness practice is proposed to target adaptive attention regulation, breaking up ruminative processing by directing attention to the embodied experience of present-moment sensations, but most research to date has focused on change in dispositional mindfulness and rumination (Alsubaie et al., 2017). Without an experimental design, it can be difficult to discern whether improvement in trait mindfulness skills and decreased dispositional rumination is a causal effect or a byproduct of symptom change following MBCT treatment (van der Velden et al., 2015). Hence, employing an experimental design, we found that a brief guided mindfulness practice was sufficient to effectively modulate cognitive, interoceptive and physiological markers amongst meditation-naïve individuals with recurrent depression. During the guided mindfulness exercise, negative thoughts became less prevalent, body awareness increased and the cardiac and respiratory rate slowed. In contrast, during depressive rumination, negative self-related thoughts increased and respiration and heart rate increased, whereas body awareness decreased. Moreover, self-reported body awareness was more than twice as high during mindfulness practice than during rumination, whereas self-related negative thoughts were more than three times as frequent during rumination than during mindfulness. These findings support the theoretical notion that states of rumination and mindfulness are likely to be incompatible modes of mind in individuals with recurrent depression, and illustrate why switching to a mindful state from a state of rumination may be an effective way to break up depressive rumination and prevent a deterioration of symptoms of depression.

These findings are consistent with an experimental study by Karl et al. (Karl et al., 2018) showing that a brief mindfulness practice can attenuate self-related negative thoughts among individuals with a history of depression in full or partial remission. Karl et al. (2018) showed that mindfulness practice attenuates self-related negative thoughts in response to a sad mood induction, whereas rumination increased negative self-related thoughts. Our findings suggest that mindfulness practice also attenuates self-related negative thoughts compared to rest without a mood induction amongst individuals in either remission or with mild-moderate symptoms of depression. Furthermore, we showed that the decrease in negative self-related thoughts occurred in parallel with an increase in body awareness, consistent with previous experimental findings on non-clinical populations and theoretical work on recurrent depression, indicating that awareness of the body and self-referential thinking may represent two distinct modes of mind (Lackner & Fresco, 2016; J. Mark G. Williams, 2008). As such, increasing body awareness during the state of mindfulness practice may be related to the ability to disengage from dysfunctional cognitive processing (N. Farb et al., 2015; Harshaw, 2015). While we cannot know how this translates into clinical outcomes, it is possible that the body serves as an anchor, allowing negative thoughts that arise in the field of awareness to be seen as just thoughts, and present moment embodied experiences may prevent new negative associations from escalating into depressive rumination (Segal et al., 2013b).

Our findings are consistent with recent evidence showing an association between mindfulness practice states and decreased respiration rate and heart rate as a reaction to formal mindfulness practice among novices and as a general trait amongst long-term practitioners (Ahani et al., 2014; N. A. Farb et al., 2013; Kirk & Axelsen, 2020; Lazar et al., 2005; Wielgosz, Schuyler, Lutz, & Davidson, 2016; Zeidan et al., 2015). The mindfulness practice increased parasympathetic nervous system response as evident in slower heart and respiration rate, whereas rumination increased sympathetic nervous system response as evident by faster heart and respiration rate. It is not clear, however, to what extent the "what" (i.e. directing attention to either the present moment embodied experience versus a negative autobiographical experience), or the "how" (i.e. relating to what is experienced with

either a non-judgmental, curious attitude versus a discrepancy-based self-reflection) or the interaction of these components caused the difference in autonomic nervous system response.

We did not find a statistically significant effect on heart rate variability across states, although there was a statistically non-significant tendency towards higher heart rate variability during mindfulness practice and lower heart rate variability during rumination. However, a limitation of this study was that we were not able to conduct an a priori power analysis, given the novelty of the design, and we may not have been powered to detect a difference in heart rate variability between brief state manipulations. Other studies have found a state effect of longer mindfulness practices (Chelidoni, Plans, Ponzo, Morelli, & Cropley, 2020; Christodoulou, Salami, & Black, 2020) in non-clinical populations. Heart rate variability abnormalities has been linked to clinical depression (Koch, Wilhelm, Salzmann, Rief, & Euteneuer, 2019), and research has shown an association between low heart rate variability and poor depression outcomes (Perna et al., 2020) and the persistence of ruminative mind states (Ottaviani, Carnevali, Thayer, & Brosschot, 2018), whereas higher heart rate variability has been related to mental health, resilience and cognitive flexibility (Perna et al., 2020). Hence, future research may want to explore whether a state of mindfulness practice or rumination differentially impacts heart rate variability amongst individuals with recurrent depression employing a bigger sample.

Another limitation of this study is that the results on the rumination state are only generalizable to the participants who were willing to participate in the rumination induction. Those not participating in the rumination condition had slightly more severe depressive symptoms, and hence the findings on the rumination state may only be generalizable to those with no residual symptoms or milder symptoms. Finally, we could not disentangle the "what" (i.e. the attentional focus) and the "how" (i.e. the attitudinal qualities) of mindfulness practice and rumination in our experiment. Future research could design more conditions to further separate the different components such as a condition where only the attentional focus is being manipulated; a condition where only the way of relating to experience is being manipulated, as well as the combination of the two elements, to further understand the role of the attentional focus and attitudinal element and how they interact. Finally, the experimental design manipulated the states of mindfulness practice, rest and rumination, and these did not occur naturally. Future research could extend this work by using a naturalistic design to explore the differences between time spent in a restful, mindful or ruminative state by employing extended experience sampling combined with physiological monitoring and app-based measurements.

CONCLUSION

In an experimental paradigm, we showed that inducing a brief state of mindfulness practice was effective in reducing negative self-related thoughts, increasing body awareness and calming autonomic nervous system response among individuals with recurrent depression, by contrasting the resting states before and after mindfulness practice, and by comparing the mindfulness meditation state to a rumination state. In contrast, the rumination state led to an increase in negative self-related thoughts, decreased body awareness and faster respiration and heart rate. These findings support the theoretical notion of mindfulness practice being an effective tool for regulating distress and negative self-related thoughts, and illustrates why switching to a mindful state from a state of rumination may be beneficial to avoid getting stuck in a vicious circle of ruminative processing and deteriorating depressive symptoms.

Data sharing statement and trial registration

Deidentified individual participant data that underlies the results reported in this article is available upon request to researchers with a methodologically sound proposal. Proposals should be directed to the corresponding author. Group data, study protocol and analytical code will be made available for download on GitHub. The study was registered at ClinicalTrials.gov (NCT03353493).

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Contributors
AMV, AR and WK were responsible for the original proposal and AMV secured funding for the trial. AMV developed the design and protocol, and AR and WK advised on the design. AMV was responsible for the general management of the study and LOF oversaw the clinical management of the study. AMV, EE and LOF collected the data. AMV, NTH, WK and AR created the analysis strategy. NTH analyzed the data. AMV, NTH, AR and WK interpreted the data. AMV wrote the initial draft. All authors contributed to, and approved, the final manuscript.

Conflicts of interest
The author(s) declares the following potential conflicts of interest. WK is the director of the Oxford Mindfulness Centre. He receives payments for training workshops and presentations related to MBCT and donates all such payments to the Oxford Mindfulness Foundation, a charitable trust that supports the work of the Oxford Mindfulness Centre. WK was until 2015 an unpaid Director of the Mindfulness Network Community Interest Company and gave evidence to the UK Mindfulness All Party Parliamentary Group. He has received royalties for several books on mindfulness published by Guilford Press. LOF is director of the Danish Centre for Mindfulness. She receives payments for presentations, workshops and teacher training related to MBSR and MBCT and donates payments to the Danish Centre for Mindfulness.

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SUPPLEMENTS

S1: Experience sampling questions

Component and questions	Resting state I+II	Mindfulness state	Rumination state
1.Manipulation check			
1.1 I felt asleep	**X**		
1.2 I kept my eyes closed	**X**		
1.3.I could follow the instructions	**X**	**X**	**X**
2. Awareness			
2.1.I was aware of my body	**X**	**X**	**X**
2.2.I was aware of my emotions	**X**		
2.3 I was aware of my thoughts	**X**	**X**	**X**
3. Affective and cognitive content			
3.1 I felt sad	**X**		
3.2 I felt happy	**X**		
3.3 I had thoughts about the past	**X**		
3.4 I had thoughts about the future	**X**		
3.5 I had negative thoughts about myself	**X**	**X**	**X**
3.6 I had positive thoughts about myself	**X**		

Table S1. Experience sampling questions after each state. Participants were asked to rate their agreement to each question in the three components on a 0-100% VAS scale (See methods for description of the paradigm). In this paper we focused on the constructs related to body-awareness and negative self-related thoughts which were prevalent across all conditions and related to our research question. However, we also compared all states on all questions. When just comparing resting states 1 and 2 on all items, the only other difference (in addition to reduced self-related thoughts) were reduced thoughts about the past (Mean difference -17, $p>0.001$) following mindfulness practice (resting state 2) compared with before the practice (resting state 1). Note we had originally planned for item 3.1 (sadness) to be measured across all states, but a programming mistake meant we got data on item 2.3 instead (thought awareness), which did not differ across states.

S2: Sample characteristics of those not participating in the rumination condition

One way ANOVA based on rumination state participation

		Sum of Squares	df	Mean Square	F	Sig.
FFMQ_change	Between Groups	74.145	1	74.145	1.060	.307
	Within Groups	4478.173	64	69.971		
	Total	4552.318	65			
EQ_change	Between Groups	10.237	1	10.237	.155	.695
	Within Groups	4233.650	64	66.151		
	Total	4243.887	65			
RRS_change	Between Groups	119.667	1	119.667	1.020	.316
	Within Groups	7506.469	64	117.289		
	Total	7626.137	65			
MAIA.NO_change	Between Groups	1.898	1	1.898	.151	.699
	Within Groups	803.633	64	12.557		
	Total	805.530	65			
MAIA.ND_change	Between Groups	.346	1	.346	.040	.842
	Within Groups	555.472	64	8.679		
	Total	555.818	65			
MAIA.EA_change	Between Groups	10.691	1	10.691	.434	.512
	Within Groups	1575.441	64	24.616		
	Total	1586.132	65			
MAIA_AR_change	Between Groups	3.270	1	3.270	.110	.741
	Within Groups	1899.215	64	29.675		
	Total	1902.485	65			
MAIA_BL_change	Between Groups	7.151	1	7.151	1.086	.301
	Within Groups	421.349	64	6.584		
	Total	428.500	65			
QIDS_change*	Between Groups	186.708	1	186.708	7.522	.008
	Within Groups	1712.616	69	24.821		
	Total	1899.324	70			

Table S2:. Comparing those who participated in the rumination condition (n=68) versus those who did not (n=20) on mechanism measures and depressive symptoms. The difference in QIDS scores were driven by higher symptoms at baseline amongst those opting out of the rumination state and there was no difference at baseline. QIDS: Quick Inventory of Depressive Symptomology (Rush et al., 2003); EQ: Experience Questionnaire(Fresco, Moore, et al., 2007); FFMQ: Five Factor Mindfulness Questionnaire(R. A. Baer et al., 2008); RRS: Rumination Response Scale(Roelofs, Muris, Huibers, Peeters, & Arntz, 2006); MAIA (Multidimensional Assessment of Interoceptive Awareness(Mehling et al., 2012).