Associations of Different Emotion Regulation Strategies with Coping-Efficacy, Rumination and Stress

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Abstract
Background  In order to investigate the relationship between stress-reactive rumination and the implementation of different emotion-regulation strategies (ERS), the pilot study at hand assessed ecological momentary assessment data twice per day from currently depressed patients (n = 21) and healthy controls (n = 23).

Methods  We analyzed differences in the implementation of ERS (body-based, behavioral, cognitive, social and multiple) and the occurrence of stress, rumination and self-efficacy between the groups as well as associations of ERS implementation at a given time-point and later levels of stress and rumination.

Results  Overall, patients reported higher subjective stress levels as well as increased ruminative thinking as a response to life stress and, in addition, a more frequent implementation of ERS. Comparing the implementation of ERS, cognitive ERS were implemented most often in the clinical group in comparison to healthy controls. All ERS were associated with increased self-efficacy at the time-point they were implemented. The implementation of cognitive ERS (e.g., reframing) at a given time-point significantly predicted reduced rumination and stress at later time-points.

Conclusions  Clinical and non-clinical groups seem to differ in their implementation of ERS. While the implementation of all investigated ERS is related to increased coping-efficacy, ERS on a cognitive level seem to be advantageous in reducing stress as well as rumination.

Keywords  Ecological momentary assessment · Experience sampling · Rumination · Stress · Depression · Emotion regulation

Introduction

Major Depressive Disorder (MDD) is one of the most prevalent mental disorders and poses a high burden for affected patients as well as society in general (American Psychiatric Association, 2013; Mathers et al., 2008). One key characteristic that is common in MDD and uniquely associated with reduced treatment success, higher risk for relapses and suicidality is rumination (Smith & Alloy, 2009). Following the original definition of depressive rumination by Nolen-Hoeksema (1991), rumination is defined as “repetitively focusing on the fact that one is depressed; on one’s symptoms of depression; and on the causes, meanings, and consequences of depressive symptoms” (Nolen-Hoeksema, 1991, p. 569) and is in the following characterized as repetitive negative self-referential thoughts about the past with little or no goal-orientation (Teismann et al., 2012). Although rumination is defined primarily as a cognitive process, it is not
only a trait-like process but also occurs in response to highly emotional situations or internal triggers, i.e., stressful life events. In this sense rumination can also be categorized as a (maladaptive) cognitive emotion regulation strategy (ERS) (Aldao & Nolen-Hoeksema, 2010; Garnefski et al., 2001; Smith & Alloy, 2009). According to the model of emotion regulation (ER) by Gross (Gross, 1998a, 1998b, 1999) there are five ways how emotions may be regulated: “(a) selection of the situation, (b) modification of the situation, (c) deployment of attention, (d) change of cognitions, and (e) modulation of responses”. (Gross, 1998a, p 271). Based on this model, cognitive ERS are consequently defined as “cognitive responses to emotion-eliciting events that consciously or unconsciously attempt to modify the magnitude and/or type of individuals’ emotional experience or the event itself” (Aldao & Nolen-Hoeksema, 2010, p. 974). Whereas various contextual factors like, for instance, intensity of emotions (Barrett et al., 2001; Dixon-Gordon et al., 2015), timing of implementation (Diedrich et al., 2016), perceived controlability of the situation (Troy et al., 2013) as well as the specific emotion to be regulated (Szasz et al., 2011) do have an impact on the adaptivity of different ERS, rumination is primarily thought to be maladaptive in contrast to potentially adaptive self-reflection (Nolen-Hoeksema et al., 2008). In the context of their emotion dysregulation model, Hofmann et al. (2012) assume that specific events trigger negative or positive affect, depending on their habitual tendency to use some ERS over others as well as some sort of diathesis. A dysregulation of negative affect and a deficiency in positive affect is then associated with psychopathology, namely mood disorders (Hofmann et al., 2012). This also stresses the importance of flexibility of choosing adaptive ERS depending on the situational demands rather than ruminating regardless of the context. Coming back to the context of stress, it has been shown that experimentally induced social stress increases rumination in participants that are prone to ruminate (De Witte et al., 2020; Gianferante et al., 2014; Hilt et al., 2015; Rosenbaum et al., 2018) and MDD patients (Rosenbaum et al., 2021). Notably, rumination—in turn—influences the stress response on a physiological level (Huffziger et al., 2013; Sladek et al., 2020) as well as later stress levels (Brosschot et al., 2006; Capobianco et al., 2018; Shull et al., 2016), most likely due to an adverse influence on the adaptation to stress. One promising approach to investigate the aforementioned constructs is using ecological momentary assessment (EMA) (Kramer et al., 2021) as in this case, it is possible to capture processes in an ecologically valid manner without retrospective biases. First investigations using EMA have shown that stress and rumination in combination have detrimental effects on psychological wellbeing. For example, Ruscio et al. (2015) investigated rumination in response to stressful life events in 145 participants with MDD, generalized anxiety disorder (GAD), comorbid MDD-GAD and healthy controls. Diagnosed participants showed higher increases in rumination following stressful life events than healthy controls, which also predicted poorer affect, increased maladaptive behavior and increased symptoms at subsequent time points. Rumination was further a mediator of the relationship between stress and affect and the relationship between stress and symptoms. Connolly and Alloy (2017) could replicate these findings using a large group of healthy controls. In their study, stress-reactive rumination predicted increases in depressive symptoms. Moberly and Watkins (2008) could further show that the ruminative self-focus predicted subsequent negative affect, but negative affect did also predict ruminative self-focus. Depressive symptoms were associated with more frequently reported negative life events, and trait rumination was positively related to reports of more severe negative events and increased reactivity to those. Summing it all up, by prolonging negative affect, rumination clearly impacts coping and coping efficacy, i.e. the individual appraisal of an effective adaption towards the demands of a stressor (Lazarus, 2000; Lazarus & Folkman, 1984). Coping-efficacy has been shown to be related to self-efficacy, psychological well-being and stress resilience (Endler et al., 2000; Maciejewski et al., 2000; McWilliams et al., 2003; Rubel et al., 2017; Southwick et al., 2005) and may even serve as a protective factor by contributing to regulation of daily physiological stress activity (Drake et al., 2016).

Due to the adverse effects of rumination, different therapeutic treatments have been developed to tackle this process (Goldberg et al., 2019; Papageorgiou & Wells, 2004). Treatments such as Rumination-Focused Cognitive Behavioral Therapy (Watkins, 2018), Mindfulness Based Cognitive Therapy (Segal et al., 2008), Acceptance and Commitment Therapy (Hayes et al., 2007), or Emotion Regulation Therapy (Watkins, 2018), Mindfulness Based Cognitive Therapy (Segal et al., 2008), Acceptance and Commitment Therapy (Hayes et al., 2007), or Emotion Regulation Therapy (Mennin & Fresco, 2013) target the relationship between stress and rumination through the implementation of new behavior, i.e., the learning and implementation of new emotion regulation strategies in response to negative rumination-eliciting life events. However, investigations on the relationship of different emotion regulation strategies and their influence on stress and rumination are, to the knowledge of the authors, mostly lacking. The present pilot study uses ecological momentary assessment to fill this gap. First, we aimed to replicate the findings of previous investigations regarding the relationship between stress and rumination at a given time point (t) with levels of rumination and stress at a later time point (t + 1). In both cases, we expected to find positive associations, translating into present stress resulting in future increases in rumination as well as more pronounced present rumination resulting in increases in future stress. Second, we wanted to investigate the predictive value of the implementation of inter- and intrapersonal emotion
regulation strategies (Hofmann, 2014) at time (t) on stress and rumination at time (t + 1). To this end, we assessed implemented ERS in an open question format and rated the answers with respect to the dimension of the implemented ERS: body-based, behavioral, social and cognitive ERS. By using an open question format, we aimed to gain an unbiased picture of the ERS used by the participants. We hypothesized that the implementation of ERS at one time point (t) should reduce stress and rumination at a later time point (t + 1).

Lastly, we explored how strongly coping-efficacy would be associated with different ERS while controlling for stress and rumination. We hypothesized to find stress and rumination at time (t) to be negatively and the implementation of different ERS to be positively associated with perceived coping-efficacy.

In order to be able to capture a broad distribution of ruminative thinking (clinical and subclinical ruminative tendencies), we assessed EMA data from 21 patients with MDD and 23 healthy controls (HC) that participated in a larger project (Rosenbaum et al., 2021).

Methods

Participants

A total of 45 participants were included in the study; however, data of one participant had to be excluded due to technical problems. The N = 44 participants included 21 patients diagnosed with MDD and 23 HC as indicated by the Structured Clinical Interview (SCID) for DSM-5 (First et al., 2015). MDD patients were diagnosed and HC screened by a trained psychologist/psychotherapist. HC were only included in case of no lifetime history of mental health disorders and no suspected disorders according to the SCID-screening.

The sample was assessed as part of a larger project investigating the effects of stress on rumination in an experimental setting (Rosenbaum et al., 2021). Both groups did not differ with respect to their age, sex, nor years of education (for more details see Table 1). The clinical group was treated with psychotherapy (59.1%) and pharmacotherapy (54.5%) at the time of the study. 15 patients were diagnosed with a recurrent MDD and 8 with a first episode MDD. The average Beck’s Depression Inventory score in the clinical sample was 24.14 (SD = 24.14) implying moderate depressive symptoms (Beck et al., 1994). Comorbid diagnoses were somatic symptom disorder (n = 2), anxiety disorders (n = 2) and personality disorders (n = 2).

Procedure

Using the PsyAssesor researcher edition V2, 2019 (Machine Learning Solutions, Luxembourg), participants were instructed to complete a questionnaire twice a day (midday and afternoon) over the course of two weeks. Participants rated their subjective stress regarding the last 5 h, as well as the extent to which it was linked to specific life events using a slider (0% = not at all; 100% = very much). Afterwards, recent life events could be reported as a free text. Furthermore, the implementation of emotion regulation strategies (“Did you use emotion regulation strategies? In case yes, which did you use? (e.g., problem-solving, social support, reappraisal, ...),” for details on the examples see supplemental material S3) and the resulting subjective coping-efficacy were reported via free text and a slider (“How effective was your stress coping?” 0% = not at all; 100% = very much), respectively. Followed by capturing the current subjective stress level, momentary perceived self-efficacy and ruminative processes were assessed using modified items of the Ruminative Response Scale (RRS; Nolen-Hoeksema, 1991), Perseverative Cognitions Questionnaire (PCQ; Szkodny & Newman, 2019) as well as a questionnaire assessing self-efficacy (SWE; Jerusalem & Schwarzer, 2003) see supplemental material table S1). Finally, participants rated their current mood using a circumplex on the axes arousal (aroused vs. relaxed) and valence (positive vs. negative).

Data Preparation

Qualitative EMA data on the causes of stress as well as the used emotion regulation strategies were categorized by two independent raters which were not involved in the EMA data collection. We found inter-rater-reliability to be high (categorization of ERS: Cohens $\kappa = 0.765$, $z = 30.9, p < .001$ (unweighted); categorization of causes of stress: $\kappa = 0.794, z = 36.6, p < .001$). Causes were grouped into the following categories: No answer, social interaction, work, private obligations, daily hassles, internal causes and political events (for information on the definition of these causes, see supplementary material S2). ERS were categorized regarding the primary emotional-behavioral level they targeted. In total,

| Table 1 Overview over the demographic variables in both subgroups (MDD and HC) as well as the total sample |
|-----------------------------------------------|
| Variable                                      | Total sample (n=44) | MDD (n=21) | HC (n=23) | Test statistic | p-value |
|-----------------------------------------------|---------------------|------------|-----------|----------------|---------|
| Age                                          | 26.22 (5.95)        | 27.14 (6.15) | 25.35 (5.75) | t(43) = 1.008 | .319    |
| Percentage female                            | 77.8%               | 77.3%      | 78.3%     | $X^2(1) = 0.006$ | .936    |
| Years of education                           | 16.19 (4.47)        | 15.82 (5.61) | 16.54 (3.10) | t(43) = -0.540 | .592    |
6 categories have been used: No reported ERS, body-based ERS (e.g., controlled breathing, relaxation, yoga, taking a bath), behavioral ERS (problem-solving, planning alternative actions, “just doing”/”keep on going”, sports/behavioral activation, time-management), cognitive ERS (distraction, mindfulness, cognitive defusion, reframing, compassion), social ERS (talking to friends, spouses, therapists) and multiple ERS (combination of the former reported categories). We chose to categorize the ERS as stated despite the fact that some strategies are related to multiple emotional-behavioral levels (e.g., cognitive and behavioral accounts), as it allows the comparison between those strategies in light of a limited sample and the need for data reduction in open answer formats. Further, we used the multiple ERS category in order to examine potential effects of increased coping-efficacy. Finally, we further excluded data entries between missing data entries so that the time between timepoint (t) and the dependent time point (t + 1) was based on subsequent measurements.

Data Analysis

First, we analyzed the implementation of emotion regulation strategies as well as differences in daily stress levels, rumination and coping-efficacy in both diagnostic groups. Therefore, we conducted a MANOVA with the between-participant factor group (MDD vs. HC) and the dependent variables person-aggregated mean stress, mean rumination and mean coping-efficacy. Further, we used Mann–Whitney-U-tests to check for differences in the average amount of different ERS and stress triggers between the subjects. To correct for multiple comparisons, we used the Benjamini–Hochberg procedure (Benjamini & Hochberg, 1995).

Further, we investigated in how far the subjective coping-efficacy at a given time point (t) was associated with the use of ERS at this time point. Prior to the analysis, predictors in all models were person-mean-centered to allow for separate analysis of within- and between-participant variability (Falkenström et al., 2017; Hoffman & Stawski, 2009). We added stress and rumination as covariates in the model to adjust for the actual occurrence of stress during this time. All parameters were entered as fixed effects besides the intercept being modeled as a random effect allowing for between-person heterogeneity in intercepts.

\[
\text{Coping}_{ti} = \beta_0 + \beta_1 (\text{Stress}_{within_i}) + \beta_2 (\text{Stress}_{between_i}) \\
+ \beta_3 (\text{Rumination}_{within_i}) + \beta_4 (\text{Rumination}_{between_i}) \\
+ \beta_5 (\text{ERS}_{within_i}) + \beta_6 (\text{ERS}_{between_i}) + \cdots + \nu_{0i} + \epsilon_{ti}
\]

Second, we investigated the rumination-stress relationship and long-term effects of different ERS on changes in rumination and stress. We fitted a multilevel model predicting the stress at one time point (t + 1) by stress and rumination levels at a previous time point (t). Rumination was entered as a time-varying within-participant and person-mean between-participant effect, thus allowing for the separation of within- and between-participant variability. Again, all parameters were entered as fixed effects besides the intercept being modeled as a random effect allowing for between-participant heterogeneity in intercepts.

\[
\text{Stress}_{t+1i} = \beta_0 + \beta_1 (\text{Stress}_{ti}) + \beta_2 (\text{Rumination}_{within_i}) \\
+ \beta_3 (\text{Rumination}_{between_i}) + \nu_{0i} + \epsilon_{ti}
\]

Further, we checked the reverse model, whether rumination at a later time point (t + 1) could be predicted by stress at a previous time point (t):

\[
\text{Rumination}_{t+1i} = \beta_0 + \beta_1 (\text{Rumination}_{ti}) + \beta_2 (\text{Stress}_{within_i}) \\
+ \beta_3 (\text{Stress}_{between_i}) + \nu_{0i} + \epsilon_{ti}
\]

With respect to our second research question, we added the predictor of ERS use, separately for body-based, cognitive and behavioral regulation as within- and between-participant predictors to our basic models:

\[
\text{Stress}_{t+1i} = \beta_0 + \beta_1 (\text{Stress}_{ti}) + \beta_2 (\text{Rumination}_{within_i}) \\
+ \beta_3 (\text{Rumination}_{between_i}) + \beta_4 (\text{ERS}_{between_i}) \\
+ \beta_5 (\text{ERS}_{within_i}) + \cdots + \nu_{0i} + \epsilon_{ti}
\]

and

\[
\text{Rumination}_{t+1i} = \beta_0 + \beta_1 (\text{Rumination}_{ti}) + \beta_2 (\text{Stress}_{within_i}) \\
+ \beta_3 (\text{Stress}_{between_i}) + \beta_4 (\text{ERS}_{between_i}) \\
+ \beta_5 (\text{ERS}_{within_i}) + \cdots + \nu_{0i} + \epsilon_{ti}
\]

Note that we did not include interactions into the models as this pilot study had a limited sample size and therefore limited power. Please also note that, due to the rather small sample size of the current study (and the number of fixed effects estimates we included in our model according to our hypotheses), this limited data does not allow for random slopes as models of interest would not converge [both models investigating the impact of rumination and ERS at one time point (t) on stress at a later time point (t + 1)]. However, we checked the models for influences of the group factor (patients vs. healthy controls) and the reported main findings of this article were not affected. Investigating the impact of day-night-shifts, we report conditional models including and excluding day-night-shifts in the following.

Furthermore, post-hoc power analyses for the mixed models are to be found in the supplemental material S4.
Results

Descriptive Analysis of ERS Implementation

We analyzed 1024 complete data entries which resulted from 23.27 (SD = 5.9) data entries per participant on average. Most of the time, no use of ERS was reported (n = 586, 57.2%). Of the 438 time points at which ERS were reported, 15.4% were cognitive, 12% behavioral, 6.7% social, 5% multiple, and 3.5% body-based. In 24% of the cases when a stress trigger was present, none of these ERS were reported (245 cases in total).

In total, body-based regulation was used 36 times, with most commonly used strategies being control of breathing (n = 14, 38.9%) and relaxation (e.g., progressive muscle relaxation) (n = 12, 33.3%). Other used strategies were resting (e.g., taking a nap) (n = 5, 13.9%) and sports (n = 5, 13.9%). Behavioral ERS were used 123 times, with problem-solving (n = 69, 56%) and behavior adaptation, e.g., working faster (n = 27, 22%), being the most used strategies. Behavioral activation (n = 16, 13%) and distraction from stress (n = 11, 9%) were used less often. With 158 times in total, cognitive strategies were reported most often and comprised greatly varied approaches including mindfulness (n = 99, 62.7%) and reframing (n = 21, 13.3%), followed by focusing on the subject (n = 11, 7%), acceptance (n = 9, 5.7%), compassion (n = 5, 3%), focus on goals (n = 4, 2.5%), reflection (n = 4, 2.5%), effortful controlling (n = 3, 1.9%) and cognitive defusion (n = 1, 0.6%). Social ERS were reported 70 times with social support (n = 44, 63%) and talks (n = 19, 27%) being the most used approaches. Lastly, multiple ERS were used in 51 cases.

Sample Characteristics: Daily stress, Rumination, Coping-Efficacy and Implementation of ERS in Depressed and Non-depressed Subjects

As expected, we found a significant effect of group, F(3, 40) = 30.316, η² = 0.305, p < .001, indicating that the MDD group showed higher average levels of daily reported stress (F(1, 42) = 15.919, p < .001, η²_p = .27) and rumination (F(1, 42) = 82.6, p < .001, η²_p = 0.66) as well as lower levels of coping-efficacy (F(1, 42) = 28.652, p < .001, η²_p = 0.41).

As reported in the first article on this dataset (Rosenbaum et al., 2021), stressful life events were reported more often in the MDD group than in the HC group (U = 365.5, Z = 2.914, p < .01) and more often due to social interactions (U = 104.5, Z = 3.230, p < .001; see Fig. 1 and 2). Note that the numbers differ slightly from the first publication on this project as one case has been excluded for this analysis due to incomplete data. Both groups used ERS similarly often; however, the MDD group used cognitive strategies significantly more often when compared to HC as indicated by a Mann–Whitney-U-test (U = 109.500, p < .01; see Fig. 3). No significant differences were observed in the frequency of implementation regarding the other ERS. Separately analyzing ERS use within the groups, Friedman nonparametric ANOVAs revealed significant differences within the clinical (χ²(4) = 25.329, p < .001) and non-clinical group (χ²(4) = 20.330, p < .001). Within the clinical group, cognitive ERS have been shown to be used more often than body-based (Z = 3.855, p_corr < .001), social (Z = 3.172, p_corr < .05)
1 and multiple ERS ($Z = 3.660, p_{corr} < .01$). In the non-clinical group, behavioral ERS were used more often than multiple ERS ($Z = 3.031, p_{corr} < .05$) and marginally more often than body-based ERS ($Z = 2.751, p_{corr} < .1$).

Contemporaneous Association of Coping-Efficacy with ERS

Analyzing the association of subjective coping-efficacy of different ERS, stress and rumination at a given time point (t) showed that both are negatively associated with coping-efficacy on a between- as well as within-participant level (see Table 2). Further, all within-participant increases in the assessed ERS were associated with increased coping-efficacy, but not on a between-participant level. When comparing beta-weights, descriptively the use of social and multiple ERS was most strongly associated with increased coping-efficacy followed by cognitive, behavioral and body-based ERS (see Table 2).

Lagged Associations Between Ruminaton and ERS at One Time Point (t) with Stress at a Later Time Point (t + 1)

Predicting stress at a later time point (t + 1) using an autoregressive model yielded significant effects for rumination on a between- as well as within-participant level. In both cases, higher rumination at the previous time point (t) was associated with relative increases in stress at a subsequent time point (t + 1). With respect to different ERS, on a within-participant level, only the use of cognitive ERS at one time point (t) was significantly associated with decreased stress at the following assessment (t + 1). In contrast, behavioral and social ERS yielded significant positive associations with stress on a between-participant level. The average stress level of a participant was positively associated with the average use of these ERS (see Table 3).

Discussion

The current study aimed to investigate the associations between rumination, daily life stress, and the use of different emotion regulation strategies (ERS). To this end, 21 patients diagnosed with MDD and 23 HC completed ecological momentary assessments (EMA) of the variables of interest regarding the last 5 h over the time course of two weeks two times per day.

On a descriptive level, different ERS were used to a different extent within and between the two groups. Cognitive ERS were used more often in the MDD group than in the HC group. Furthermore, within the MDD group, cognitive ERS were the most frequently used ERS. In contrast, within the healthy sample more or less all ERS were used to a similar extent with only behavioral strategies showing tendencies towards more frequent use. One potential explanation for this might be the characteristics of the samples: The clinical group was in great parts treated with psychotherapy and in most cases by cognitive behavioral approaches that emphasize the training of cognitive ERS. Further, the healthy control group reported fewer stress triggers and lower levels of stress in general, indicating that this group had no need to regulate that often and therefore was not only using cognitive ERS but ERS in general less often. As expected, participants with MDD rated themselves as more stressed, reported more frequent rumination and less effective coping.

Investigating the relationship between coping-efficacy and different ERS while controlling for stress and rumination, we
observed positive associations between all within-participant variations in the assessed ERS and coping-efficacy. Descriptively, the use of social and multiple ERS was most strongly associated with increased coping-efficacy, followed by cognitive, behavioral and body-based ERS. Given the negative association between coping-efficacy and psychological distress, and the important role of coping-efficacy as a therapeutic factor of change, respectively, this result supports and guides the clinical implementation of skills. For example, other studies could already show that an intense emotion regulation skills training in MDD significantly improves the efficacy of CBT (Berking et al., 2013) and that the successful use of ER-skills is substantially linked to symptom severity in depression (Berking et al., 2014) but also anxiety (Wirtz et al., 2014). In the selection of which ERS might be most effective in increasing coping-efficacy, those strategies might be reasonable starting points for interventions, prior to restricting to one specific behavioral, cognitive or body-based ERS. However, it is important to emphasize that the current study does not provide data for direct comparisons between specific types of strategies (e.g., cognitive strategy rephrasing vs. acceptance) and, therefore, further research is needed to answer this question.

| Parameter estimates | Model including day-night-shifts | Model excluding day-night-shifts | Model with only day-night-shifts |
|---------------------|----------------------------------|----------------------------------|----------------------------------|
|                     | Estimate (SE) | CI [5%; 95%] | t | Estimate (SE) | CI [5%; 95%] | t | Estimate (SE) | CI [5%; 95%] | t |
| Fixed effects       |                   |                  |   |                   |                  |   |                   |                  |   |
| Intercept           | 65.02 (1.95)     | [61.77; 68.29]  | 33.319***| 63.21 (2.04)     | [59.81; 66.63]  | 30.952***| 65.03 (1.95)     | [61.77; 68.29]  | 33.319***|
| WP: Rumination      | – 7.37 (1.42)   | [– 9.71; – 5.03]| – 5.183***| – 6.82 (2.31)   | [– 10.64; – 3.01]| – 2.947***| – 7.37 (1.42)   | [– 9.71; – 5.03]| – 5.183***|
| BP: Rumination      | – 12.91 (4.07)  | [– 19.69; – 6.08]| – 3.170**| – 12.55 (4.35)  | [– 19.76; – 5.23]| – 2.886**| – 12.91 (4.07)  | [– 19.69; – 6.08]| – 3.170**|
| WP: stress          | – 0.39 (0.03)   | [– 0.45; – 0.34]| – 11.465***| – 0.44 (0.05)   | [– 0.52; – 0.35]| – 8.065***| – 0.39 (0.03)   | [– 0.45; – 0.34]| – 11.465***|
| BP: Stress          | – 0.25 (0.20)   | [– 0.59; 0.09]  | – 1.239| – 0.28 (0.21)   | [– 0.64; 0.07]  | – 1.357| – 0.25 (0.20)   | [– 0.59; 0.09]  | – 1.239|
| WP: ERS-body        | 11.45 (4.11)    | [4.68; 18.23]   | 2.783**| 14.46 (6.09)    | [4.42; 24.50]   | 2.375*| 11.46 (4.12)    | [4.68; 18.23]   | 2.783**|
| BP: ERS-body        | 4.36 (39.06)    | [– 61.00; 69.54]| 0.112| 18.47 (40.80)   | [– 50.02; 86.44]| 0.454| 4.37 (39.06)    | [– 61.00; 69.54]| 0.112|
| WP: ERS-behavior    | 12.23 (2.52)    | [8.08; 16.38]   | 4.850***| 13.25 (4.13)    | [6.44; 20.06]   | 3.205**| 12.23 (2.52)    | [8.08; 16.38]   | 4.850***|
| BP: ERS-behavior    | 23.19 (17.05)   | [– 5.25; 51.76] | 1.360| 19.33 (17.71)   | [– 10.26; 48.96]| 1.092| 23.20 (17.06)   | [– 5.25; 51.76] | 1.360|
| WP: ERS-cognition   | 12.57 (2.53)    | [8.39; 16.75]   | 4.950***| 11.17 (4.07)    | [4.46; 17.90]   | 2.743**| 12.57 (2.54)    | [8.39; 16.75]   | 4.950***|
| BP: ERS-cognition   | 13.77 (11.34)   | [– 5.18; 32.70] | 1.214| 14.59 (12.28)   | [– 6.03; 34.99] | 1.189| 13.78 (11.35)   | [– 5.18; 32.70] | 1.214|
| WP: ERS-social      | 16.99 (3.34)    | [11.48; 22.50]  | 5.073***| 11.57 (6.09)    | [1.53; 21.61]   | 1.901#| 16.99 (3.35)    | [11.48; 22.50]  | 5.073***|
| BP: ERS-social      | 7.84 (19.69)    | [– 25.04; 40.76]| 0.398| 20.76 (20.45)   | [– 13.33; 55.07]| 1.015| 7.84 (19.69)    | [– 25.04; 40.76]| 0.398|
| WP: ERS-multiple    | 16.62 (4.13)    | [9.83; 23.43]   | 4.025***| 19.39 (5.99)    | [9.52; 29.27]   | 3.236**| 16.63 (4.13)    | [9.83; 23.43]   | 4.025***|
| BP: ERS-multiple    | 20.46 (18.26)   | [– 10.07; 50.98]| 1.121| 21.70 (18.53)   | [– 9.28; 52.80] | 1.171| 20.47 (18.26)   | [– 10.07; 50.98]| 1.121|

Random effects

| Parameter | VAR (SD) | VAR (SD) | VAR (SD) |
|-----------|----------|----------|----------|
| Intercept | 142.4 (11.93) | 123.0 (11.09) | 142.36 (11.93) |
| Residual  | 505.1 (22.47)  | 524.8 (22.91)  | 505.12 (22.48) |

WP Within-participants, BP Between-participants

*** p < .001, ** p < .01
Table 3: Impact of rumination and ERS at one time point (t) on stress at a later time point (t + 1)

| Parameter estimates | Model 1 including day-night-shifts | Model 1 excluding day-night-shifts | Model 1 with only day-night-shifts |
|---------------------|------------------------------------|-----------------------------------|----------------------------------|
|                     | Estimate (SE) CI [5%; 95%] t        | Estimate (SE) CI [5%; 95%] t        | Estimate (SE) CI [5%; 95%] t        |
| Fixed effects       |                                    |                                   |                                  |
| Intercept           | 0.19 (1.38) [−2.12; 2.51] 0.137    | 0.84 (1.51) [−1.69; 3.39] 5.324    | 0.19 (1.39) [−2.12; 2.51] 0.137    |
| Stress (t)          | 0.18 (0.03) [0.12; 0.24] 5.247***  | 0.26 (0.05) [0.17; 0.34] 1.681***  | 0.18 (0.03) [0.12; 0.24] 5.247***  |
| WP: rumination      | 3.07 (1.49) [0.57; 5.56] 2.059*    | 3.84 (2.28) [−0.04; 7.71] 5.670#   | 3.07 (1.49) [0.57; 5.56] 2.059*    |
| BP: rumination      | 10.99 (1.93) [7.80; 14.27] 1.93*** | 12.50 (2.20) [8.86; 16.25] 0.552***| 10.99 (1.03) [7.80; 14.27] 5.692***|
| Random effects      | VAR (SD)                           | VAR (SD)                          | VAR (SD)                          |
| Intercept           | 58.11 (7.62)                       | 42.71 (6.54)                      | 58.11 (7.62)                      |
| Residual            | 569.45 (23.86)                     | 553.19 (23.52)                    | 569.45 (23.86)                    |

| Parameter estimates | Model 2 including day-night-shifts | Model 2 excluding day-night-shifts | Model 2 with only day-night-shifts |
|---------------------|------------------------------------|-----------------------------------|----------------------------------|
|                     | Estimate (SE) CI [5%; 95%] t        | Estimate (SE) CI [5%; 95%] t        | Estimate (SE) CI [5%; 95%] t        |
| Fixed effects       |                                    |                                   |                                  |
| Intercept           | 0.08 (1.15) [−1.85; 2.01] 0.069    | −1.20 (6.10) [−11.28; 8.86] 0.641 | −0.44 (1.25) [−2.54; 1.66] −0.354 |
| Stress (t)          | 0.18 (0.03) [0.13; 0.25] 5.395***  | 0.24 (0.05) [0.15; 0.33] 4.767***  | 0.23 (0.05) [0.15; 0.31] 4.879***  |
| WP: rumination      | 3.35 (1.49) [0.84; 5.85] 2.242*    | 4.54 (2.28) [0.66; 8.40] 1.989*    | 1.91 (2.03) [−1.40; 5.21] 0.962*   |
| BP: rumination      | 11.57 (1.90) [8.43; 14.79] 6.077***| 13.54 (2.28) [9.45; 17.66] 5.499***| 9.18 (2.13) [5.68; 12.79] 4.315*** |
| WP: ERS-body        | 2.85 (4.35) [−4.43; 10.03] 0.656   | −1.20 (6.10) [−11.28; 8.86] 0.641 | 6.83 (6.37) [−3.67; 17.32] 1.073   |
| BP: ERS-body        | −39.78 (22.62) [−77.58; -1.79] 1.758# | −28.61 (22.11) [−75.58; 18.63] 1.018 | −50.93 (24.52) [−91.86; 3.93] 2.077# |
| WP: ERS-behavior    | −1.68 (2.66) [−6.09; 2.71] 0.63    | −1.67 (4.11) [−8.52; 5.16] 0.406   | −1.72 (3.54) [−7.56; 4.11] 0.486   |
| BP: ERS-behavior    | 22.80 (9.60) [6.79; 38.95] 2.375*  | 19.88 (11.87) [10.12; 39.92] 1.674  | 23.71 (10.40) [6.37; 41.15] 2.281*  |
| WP: ERS-cognition   | −5.81 (2.68) [−10.24; 1.39] 2.163* | −10.41 (4.07) [−17.13; 3.69] 2.555* | −2.74 (3.62) [−8.71; 3.23] 0.756*  |
| BP: ERS-cognition   | 0.63 (6.84) [−10.74; 12.16] 0.63   | −1.43 (8.75) [−15.89; 13.45] 0.163 | 2.67 (7.42) [−9.72; 15.06] 0.359   |
| WP: ERS-social      | −4.82 (3.54) [−10.67; 1.01] 1.36   | 3.85 (6.11) [−6.24; 13.93] 0.630   | −8.85 (4.40) [−16.10; 1.60] 2.011   |
| BP: ERS-social      | 32.48 (10.91) [14.36; 50.90] 2.977**| 17.57 (13.45) [−4.84; 40.20] 1.306 | 41.79 (12.04) [21.81; 62.03] 3.470**|
| WP: ERS-multiple    | 0.49 (4.36) [−6.72; 7.69] 0.133    | 3.84 (6.01) [−6.11; 13.77] 0.639   | −8.06 (6.54) [−18.86; 2.73] −1.323  |
| BP: ERS-multiple    | −9.01 (10.53) [−26.66; 8.69] 0.855  | −3.34 (12.52) [−24.30; 17.84] −0.266 | −15.67 (11.83) [−35.40; 4.13] −1.325 |
| Random effects      | VAR (SD)                           | VAR (SD)                          | VAR (SD)                          |
| Intercept           | 32.65 (5.71)                       | 33.9 (5.82)                       | 23.5 (4.85)                       |
| Residual            | 565.69 (23.78)                     | 538.6 (23.21)                     | 571.1 (23.90)                     |

WP: Within-participants, BP: Between-participants
*** p < .001, ** p < .01, * p < .05, # p < .1
The analysis of the influence of ERS on stress and rumination at later time points in time-lagged models yielded some interesting and promising effects. First of all, rumination at one time point (t) influenced changes in stress at a later time point (t + 1), but not vice versa. This result is well in line with previous investigations showing the potential causal mechanism between rumination and stress as assessed with momentary assessment (Connolly & Alloy,
Interventions might show sustainable effects as the intersubjective stress are mostly cognitive processes, cognitive may concern the level of intervention. As rumination and lasting effects of cognitive ERS on stress and rumination vs. long-term effects). Another interpretation for the long- efficacy) and different time-dependent effects (direct effects with decreases in stress and rumination following their implementation. Most importantly, this effect yielded significance despite cognitive ERS not being the most strongly associated with rumination at later time points that might yield significance in larger sample sizes. Nonetheless, the current results show that cognitive strategies are indeed significantly associated with decreases in stress and rumination following their implementation. Most importantly, this effect yielded significance despite cognitive ERS not being the most strongly associated with coping-efficacy in comparison to other ERS. This discrepancy hints towards different effects of ERS on different outcome measures (stress, rumination, coping-efficacy) and different time-dependent effects (direct effects vs. long-term effects). Another interpretation for the long-lasting effects of cognitive ERS on stress and rumination may concern the level of intervention. As rumination and subjective stress are mostly cognitive processes, cognitive interventions might show sustainable effects as the intervention targets the same level of processing. It will be an interesting endeavor for future research to investigate the relationship between stress and ERS depending on the target level, e.g., behaviorally vs. cognitively focused ERS.

Interestingly, on a between-participant level some diverging effects have been observed. While behavioral and social ERS were positively associated with stress at later time points, behavioral ERS were negatively associated with rumination at later time points on a between-participant level. These results emphasize the importance of separating within- and between-participant effects in EMA data, as between-participant effects are more ambiguous in their interpretation than within-participant effects. In contrast to between-participant associations, within-participant associations cannot be confounded by stable between-person characteristics and thus allow firmer conclusions regarding the true nature of the association (e.g., Falkenström et al., 2020). The positive association between ERS and stress on a between-participant level could be due to increased ERS use in participants that are more stressed, or contrary to our effect of the within-participant effects, that participants are more stressed if they use ERS. Although the interpretation that ERS are more frequently used in participants that are more stressed is in line with other longitudinal observations (Everaert & Joormann, 2020), it remains puzzling why the between-participant associations are positive with respect to stress and negative with respect to rumination as dependent variables. One potential explanation for this might be that on a between-subject level, subjects regularly experiencing high levels of stress regulate their emotions more and, consequently, these adaptive coping strategies replace the maladaptive strategy of rumination.

Despite these promising findings, some limitations of this study have to be noted. First, as already mentioned, the study at hand was designed as a pilot study and therefore the investigated sample is rather small and further investigations gathering larger sample sizes are needed. Future studies with larger sample sizes, random slope effects could be modeled as well. Further, we categorized the reported ERS of the participants into six different groups even though there might be overlaps between these categories; e.g., problem-solving might be classified as a behavioral as well as a cognitive ERS. In future studies, concrete ERS should be investigated in larger samples to examine the impact of different ERS in greater detail. Then, it will be possible to set up structural equation models investigating more complex relationships as well as interactions between stress, rumination and ERS. Nonetheless, the current study showed that ERS influences rumination as well as stress and that EMA has several advantages in investigating these relationships in real life settings, offering a promising tool for future investigations (Rosenkranz et al., 2020). By assessing EMA data, recall biases influence internal validity to a lesser extent than diary data or questionnaire investigations, and changes over time can be more reliably assessed as there is a relatively short lag between experiencing and reporting.

In summary, we found that clinical and non-clinical groups differed in their implementation of ERS, which might be due to different characteristics of these samples. All investigated ERS are related to coping-efficacy. Rumination at a given time influences changes in stress at later time points but not vice versa. ERS on a cognitive level seem to be advantageous in reducing stress as well as rumination.

Future research should focus on the specific temporal dynamics of ruminative processes and further investigate the strategy-dependent efficacy in coping with stressful life events in order to disentangle the relationship of stress, rumination and depressive symptoms.
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Declarations

Conflict of Interest David Rosenbaum, Isabella Int-Veen, Julian Rubel, Hendrik Laicher, Agnes Kroczek, Glenn Lawyer, Andreas J. Fallgatter, Ann-Christine Ehlis declare that they have no conflict of interest.

Animal Rights No animal studies were carried out by the authors for this article.

Informed Consent All subjects gave their informed consent to participate in the study and this study was approved by the ethics committee of the University of Tuebingen.

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