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Repetitive negative thinking in daily life predicts psychopathology: Further validation of an ecological momentary assessment paradigm☆

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ABSTRACT

Background: Repetitive negative thinking (RNT) is an important transdiagnostic process involved in the development and maintenance of psychopathology. In a previous study, we developed an Ecological Momentary Assessment (EMA) paradigm to assess RNT in daily life. This study aimed to replicate and extend earlier findings on the reliability and validity of the EMA paradigm, including the prediction of future mental health. In exploratory analyses, the predictive utility of dynamic patterns of RNT, such as stress-reactive RNT, variability, inertia, and instability of EMA-based RNT was investigated.
Methods: 220 students filled out questionnaires (trait RNT, mental health-related measures) and completed the EMA-based RNT assessment five times daily for ten days on smartphones at the start of their semester. At the end of the semester, students filled out the same questionnaires during a high stress period.
Results: The reliability and validity of a process-related RNT scale for use in EMA was confirmed as it showed high reliability within and between persons. Furthermore, EMA-based RNT significantly predicted symptoms of depression and anxiety after three months over and above baseline symptoms and trait RNT. Of the dynamic RNT parameters, RNT instability and variability significantly predicted psychopathology over and above mean EMA-based RNT.
Discussion: Findings support the reliability and validity of the process-related measure of RNT in daily life, but not the hybrid measure. In addition, our results suggest that dynamic patterns of EMA-based RNT enhance the prediction of psychopathology beyond mean EMA-based RNT. Generalizability of findings is limited as a homogenous student sample was tested.

1. Introduction

Repetitive negative thinking (RNT) has been identified as a transdiagnostic process involved in the development and maintenance of different mental disorders, including major depressive disorder (MDD), and generalized anxiety disorder (GAD; Kircanski et al., 2015; McEvoy et al., 2013; Spinhoven et al., 2015, 2018). RNT can be defined as a cognitive process characterized by repetitive, intrusive, and relatively uncontrollable thoughts about negative content (Ehring & Watkins, 2008). Therefore, RNT encompasses both the concept of rumination (Nolen-Hoeksema & Morrow, 1991) and worry (Borkovec et al., 1983), which share the same processes while mainly differing in their temporal orientation (Ehring & Watkins, 2008; McEvoy et al., 2013; Spinhoven et al., 2015).

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1.1. Assessing RNT using ecological momentary assessment

RNT is commonly measured using trait self-report questionnaires asking participants about their typical thinking style. Examples are the Penn State Worry Questionnaire (PSWQ; Molina & Borkovec, 1994), the Ruminative Responses Scale (RRS; Nolen-Hoeksema & Morrow, 1991), or the Perseverative Thinking Questionnaire (PTQ; Ehring et al., 2011). However, such questionnaires can be biased by memory and state factors (Conner & Barrett, 2012; Schwarz et al., 2009). Furthermore, trait questionnaires can be expected to mainly assess metacognitive beliefs about RNT rather than accurately representing the frequency and/or severity of this phenomenon in daily life. Recently, Ecological Momentary Assessment (EMA; Shiffman et al., 2008) has gained popularity in mental health research. EMA can be used to assess various cognitive, emotional, behavioral, and physiological variables in a naturalistic setting multiple times per day across several days or weeks. Therefore, it possesses high ecological validity and can reduce memory bias by asking participants in (near) real time about their experiences (Conner & Barrett, 2012; Trull & Ebner-Priemer, 2013).

The EMA method has also been applied to the assessment of RNT, asking participants repeatedly in daily life how much they currently engage in rumination, worry, or other form of repetitive thinking at each assessment point (e.g., Hjartarson et al., 2022; Rosenkranz et al., 2020; Ruscio et al., 2015; Thielsch et al., 2015). Results showed that EMA-based RNT is significantly related to different mental health outcomes, including symptom severities of depression and anxiety, while typically only showing small to moderate associations with traditional trait questionnaire measures of RNT (e.g., Connolly & Alloy, 2017; Kornacka et al., 2021; Pasyugina et al., 2015; Rosenkranz et al., 2020; Timm et al., 2017). The associations between EMA-based RNT with psychopathology but the low overlap with trait RNT questionnaire suggests that EMA-based RNT measures have clinical validity and may capture aspects of RNT that traditional self-report measures do not. Therefore, the assessment of EMA-based RNT appears highly promising for basic as well as intervention studies in this area. However, past studies were limited in that they have mostly used items to assess RNT via EMA that had been developed ad hoc and have not been formally validated.

1.2. Validation of an EMA paradigm assessing RNT

In a previous study, Rosenkranz et al. (2020) developed and validated an EMA paradigm to assess RNT as an individual difference variable, i.e. approximating the tendency to engage in RNT by averaging person means across the EMA phase (Rosenkranz et al., 2020). Several items were included in the paradigm based on literature research and theoretical considerations, including items reflecting the *content* vs. the *process* of RNT. In this earlier study, two promising scales were identified to measure RNT using EMA. One scale was based on a hybrid model including both RNT *content* and *processes*, encompassing two commonly used items assessing momentary thinking about feelings and problems, respectively (Moberly & Watkins, 2008), and two process-related items assessing difficulty to disengage from thoughts (uncontrollability) and subjective burden of RNT (distress). The second scale exclusively consisted of items focusing on the transdiagnostic *process* of RNT, assessing the three core processes of repetitiveness, intrusiveness, and difficulty to disengage from thoughts adapted from the PTQ (Ehring et al., 2011). Additionally, subjective burden/distress was again included in the scale. Both EMA scales showed good concurrent validity with trait questionnaires and symptom measures, as well as high reliability. Furthermore, findings of this previous study revealed that a sampling design of five daily assessments across ten consecutive days yielded an optimal tradeoff between information gain and participant burden (Rosenkranz et al., 2020). That is, a high percentage of the total information was retained with this sampling design, yielding estimates of person level parameters of RNT, such as person mean, variability, and instability.

However, the Rosenkranz et al. (2020) study was limited by the use of a cross-sectional design, allowing to merely test concurrent associations between EMA-based RNT, trait RNT questionnaires, and symptom severity measures. It therefore remains to be tested whether EMA-based RNT also predicts *future* psychopathology when controlling for baseline symptom levels, and how the prediction by an EMA-based RNT assessment compares to traditional trait questionnaires.

1.3. Assessing dynamic processes related to RNT

In an EMA paradigm, trait-like variables can be approximated by averaging the scores of multiple daily assessments across a chosen period. In addition, EMA provides a micro-level perspective on clinically relevant processes as they occur in daily life (Myin-Germeys et al., 2018; Wichers, 2014). Investigating dynamic patterns of RNT on a micro-level could improve the prediction of psychopathology.

Based on previous literature, at least four different ways of assessing dynamic processes in RNT appear promising. First, several earlier EMA studies have focused on levels of rumination in response to negative events, i.e., *stress-reactive rumination*. Results show that stress-reactive rumination is not only more pronounced in patients with GAD and MDD compared to healthy controls, but also predicts future increases in depressive symptoms (Connolly & Alloy, 2017; Moberly & Watkins, 2008; Ruscio et al., 2015). Second, in a recent study the *instability* of momentary rumination was investigated, that is, the frequency and magnitude of fluctuations in RNT over time (Timm et al., 2017). Higher instability of RNT significantly predicted elevated levels of depression after 6 and 36 months over and above average EMA-based RNT and trait RNT. Instability is itself measured by the mean squared successive difference (MSSD) and is composed of *variability* and *inertia*. Variability reflects the range of intensity with which a person experiences RNT as measured by the within-person standard deviation (SD) indicative of the amplitude of change. Inertia reflects an individual's resistance to changing their level of RNT, as measured by the autocorrelation, indicating difficulties in disengaging from RNT once it has been triggered (see Houben et al., 2015 for a conceptual description; see Jahng et al., 2008 for similar indicators in the field of emotion research). While these parameters have been studied extensively in the context of emotion dynamics (e.g., Nelson et al., 2020; Trull et al., 2015), only recently studies have started to investigate these dynamic parameters in the context of RNT, while most studies focused specifically on dynamic aspects of rumination.

Ruminative inertia has been associated with current depressive symptoms (Bean & Ciesla, 2024; Bean et al., 2020), but findings on RNT inertia predicting psychopathological symptoms are mixed. Specifically, Bean and Ciesla (2024) showed that ruminative inertia did not predict future psychopathological symptoms (i.e., depression, general anxiety, or social anxiety), and Bean et al. (2020) even showed a negative association between ruminative inertia and the number of past depressive episodes. In contrast, Funk et al. (2025) demonstrated that RNT inertia predicted depressive symptoms at a one-month follow-up but not at baseline, three-month, or twelve-month assessments. RNT variability appears to be more consistently linked to psychopathological symptoms, yet the specificity of this association remains unclear. While Bean and Ciesla (2024) found that ruminative variability predicted future symptoms of depression and social anxiety, but not general anxiety, Funk et al. (2025) showed that RNT variability predicted increases in generalized anxiety symptoms, but not depressive symptoms or well-being. The role of RNT instability was so far only examined in one study (Funk et al., 2025), showing that that lower RNT instability was associated with higher depressive symptoms at baseline, but did not predict psychopathological symptoms at later time points. In sum, the current literature yields inconsistent findings, underscoring the need for further research that simultaneously examines multiple dynamic parameters of RNT in relation to a broad spectrum of psychopathological symptoms.

1.4. The current study

The first aim of this study was to cross-validate the novel EMA paradigm developed by Rosenkranz et al. (2020). Specifically, we adopted the proposed sampling design in a non-clinical sample. The cross-validation and extension of findings followed several steps using a longitudinal design to investigate the predictive utility of static (i.e., person-level mean) as well as dynamic parameters (i.e., instability, inertia, variability, and stress-reactive RNT).

In Step 1, the robustness of both previously developed scales (process-related vs. hybrid) was tested by investigating whether model fit and reliability within and between persons found in our earlier study could be replicated.

In Step 2, we explored the construct validity of the EMA paradigm by examining concurrent correlations between EMA-based RNT with similar constructs aiming to replicate the Rosenkranz et al. (2020) findings.

In Step 3, we aimed to extend the Rosenkranz et al. (2020) validation findings by testing whether EMA-based RNT shows associations with affect and stressors as would be predicted by theory and earlier research. First, based on previous studies showing that negative affect (NA) and RNT are strongly associated (e.g., Moberly & Watkins, 2008), we expected to find a reciprocal relationship between EMA-based RNT and NA within persons; i.e. higher RNT in a previous assessment should predict NA in a subsequent assessment and vice versa. Second, since RNT has been shown to covary with stressful events (e.g., Genet & Siemer, 2012), we expected to replicate this finding by demonstrating a contemporaneous association between RNT and stressful events using our EMA paradigm as well, which would further establish concurrent validity.

In Step 4, we tested the predictive validity of our EMA paradigm and hypothesized that person mean higher EMA-based RNT significantly predicts higher levels of depression, anxiety, stress symptoms, and lower levels of mental well-being in a high stress period over and above baseline symptoms and trait RNT assessed via self-report questionnaires.

In our second aim, we tested whether dynamic parameters of RNT, specifically higher levels of stress-reactive rumination, higher instability, higher variability, and higher inertia were predictive of higher levels of psychopathological symptoms (i.e., depression, anxiety, and stress) and lower levels of well-being over and above person mean EMA-based RNT scores.

2. Methods

2.1. Participants

A total of 220 participants (Age: $M = 21.34$, $SD = 3.5$, range: 18–35, 76 % female) were recruited in Munich and Regensburg via posters, online postings in local student groups, and announcements in student lectures. Participants were included in the study if they were currently enrolled at a university, spoke German at a native speaker level, and were currently not undergoing psychological treatment for mental health problems or suffering from a mental disorder (assessed with two brief self-report items). Participants received either course credit or monetary compensation. Participants opting for monetary compensation received 8€ per hour for baseline and follow-up assessments and had the chance to win one of five 50€ vouchers depending on their compliance in EMA. Course credit was given for both assessments and based on compliance in EMA. All participants completing the follow-up assessment of the study entered a raffle to win one of ten 20€ vouchers. Two participants had to be excluded post-hoc due to fulfilling the exclusion criterion of suffering from a mental disorder, which they had not disclosed in the initial screening but spontaneously revealed this information during the course of the study.

2.2. Self-report trait questionnaires

Ruminative Response Scale – Brooding (RRS-b). Depressive rumination was measured using the 5-item brooding subscale (RSS-b; Treynor et al., 2003) of the Ruminative Response Scale (German version: Huffziger & Kühner, 2012). In the RRS-b, items are rated on a scale from 1 ("never") to 4 ("almost always"). The RRS-b was shown to have acceptable internal consistency and good predictive validity (Treynor et al., 2003). In the current study, the internal consistency was $\alpha = .66$.

Penn State Worry Questionnaire (PSWQ). Worrying was assessed using the PSWQ (PSWQ; Meyer et al., 1990; German version: Stöber, 1995). Sixteen statements are evaluated on a 5-point scale (1 = "not at all typical of me", 5 = "very typical of me"). The PSWQ shows good construct validity and internal consistency ranges from good to excellent (Kertz et al., 2014; Topper et al., 2014; Wuthrich et al., 2014). In the current sample, internal consistency of the PSWQ at baseline was excellent with $\alpha = .90$.

Perseverative Thinking Questionnaire (PTQ). Transdiagnostic process characteristics of RNT (e.g., repetitiveness, intrusiveness, uncontrollability) were measured using the PTQ (Ehring et al., 2011). Fifteen items are rated from 0 ("never") to 4 ("almost always"). Good construct validity and high internal consistency has been reported for the PTQ (Ehring et al., 2011; McEvoy et al., 2018). The PTQ at baseline showed excellent internal consistency of $\alpha = .94$ in our sample.

Generalized Anxiety Disorder Questionnaire (GAD-7). The Generalized Anxiety Disorder questionnaire (GAD-7; Spitzer et al., 2006) assesses the presence and severity of seven GAD symptoms over the past two weeks on a 4-point scale (0 = "not at all" to 3 = "nearly every day"). High internal consistency has been reported (Löwe et al., 2008; Wild et al., 2016). In our study, internal consistency of the GAD-7 at baseline was good with $\alpha = .81$.

Patient Health Questionnaire (PHQ-9). Depression was assessed using the depression module of the Patient Health Questionnaire (PHQ-9; Kroenke et al., 2001). The presence of all nine DSM-IV criteria for Major Depressive Disorder are rated from 0 ("not at all") to 3 ("nearly every day") regarding the past two weeks. The PHQ-9 has excellent internal reliability and shows high sensitivity and specificity (Kroenke et al., 2001) and good criterion validity (Löwe et al., 2004). In our sample, the PHQ-9 at baseline showed acceptable internal consistency with $\alpha = .72$.

Depression-Anxiety-Stress-Scales (DASS). The Depression-Anxiety-Stress-Scales (DASS; Lovibond & Lovibond, 1995; Nilges & Essau, 2015) were used to assess symptoms of depression, anxiety, and stress over the past week. Forty-two items are rated on a 4-point scale (0 = "did not apply to me at all" to 3 = "applied to me very much, or most of the time"). All three subscales show good construct validity and high reliability (Crawford & Henry, 2003; Nilges & Essau, 2015). The DASS subscales at baseline showed acceptable internal consistency for the anxiety subscale ($\alpha = .68$) and good internal consistencies for the stress ($\alpha = .76$) and the depression subscale ($\alpha = .86$).

Short Warwick-Edinburgh Mental Well-Being Scale (SWEMWBS). The Short Warwick-Edinburgh Mental Well-Being Scale (SWEMWBS) was used to capture mental well-being (see Jahng et al., 2008). Eudemonic and hedonic well-being, as well as psychological functioning and subjective well-being are assessed, including satisfying interpersonal relationships (e.g., feelings of closeness and being loved), positive functioning (e.g., autonomy, confidence, and clear thinking) and positive affect (e.g., relaxation, optimism). Seven items are rated on a 5-point scale (1 = "none of the time" to 5 = "all of the time") regarding the past two weeks. The SWEMWBS possess adequate construct validity and acceptable internal consistency (McKay & Andretta, 2017; Stewart-Brown et al., 2011). In our sample, internal consistency was acceptable with $\alpha = .73$.

2.3. Ecological momentary assessment (EMA)

Participants received five notifications per day for a period of ten consecutive days. Daily notifications were sent in a pseudorandomized way over a 10-h time window starting either from 9am, 10am, or 11am depending on participants' preference. When receiving a notification, participants were given 30 min to start answering 9 to 10 questions about momentary mood, negative events since the last notification, and current content and processes of RNT (see Table 1). Participants were reminded 5, 10, and 20 min after the notification if they had not answered the questions up to this point. No answer was possible after 30 min.

Momentary Mood. First, participants rated their momentary mood in terms of arousal and valence. We used four bipolar items that have been recommended for EMA research and have been used in previous studies (e.g., Huffziger & Kühner, 2012; Wilhelm & Schoebi, 2007). Wilhelm and Schoebi (2007) reported good reliability both for valence (between-persons = 0.92, within-persons = 0.70) and arousal (between-persons = 0.90, within-persons = 0.70) based on generalizability theory (Shrout & Lane, 2012). As the focus of this study was the validation of a brief assessment instrument for RNT, we decided to collapse the two items of each scale into a combined item, yielding two bipolar items measuring valence and arousal. For the current analyses, only the item assessing valence was used as the indicator of momentary mood.

Negative Events. Participants were asked whether they had experienced a stressful negative event since the last beep, similar to other studies (Huffziger et al., 2013). If participants affirmed this question, they were asked to indicate the emotional impact of this event on a 7-point Likert scale.

Momentary Repetitive Negative Thinking. Items assessing momentary RNT were based on our previous study, which had yielded two candidate scales for assessing RNT (see Table 1). Detailed information on the adaptation of the items and the rationale for including these items can be found in Rosenkranz et al. (2020). Only minimal changes in wording were applied before using the same items in the current study (see Table 1; for the original items written in German see https://osf.io/yuhc3/). Item order within the EMA paradigm was additionally changed to test robustness of the previous findings.

Process-related model. The process-related model encompassed the core processes repetitiveness (RPT), intrusiveness (INTR), and uncontrollability (CTRL) of RNT (adapted from the PTQ; Ehring et al., 2011) and one item measuring subjective burden/distress (BUR).

Hybrid model. An exploratory hybrid model was retained in the previous study, encompassing two content-related items asking participants how much they are currently thinking about their feelings and their problems, respectively taken from Moberly and Watkins (2008). Furthermore, this model included two process-related items, i.e., uncontrollability (CTRL) and subjective burden of negative thoughts (BUR).

Table 1
EMA paradigm: Items assessing repetitive negative thinking and changes to previous study.

Mood		Item	Scale
1.	Valence (VAL) *	How do you feel right now?	1: "discontent/bad", 7: "content/well"
2.	Arousal (ARL)	How do you feel right now?	1: "agitated/tense", 7: "calm/relaxed"
Negative Event			
3.1	Negative event (NE)	*Since the last beep, have you experienced something that has burdened you greatly?*	0: "no", 1: "yes";
3.2	Intensity (NE-I)	*How negative was this event for you?*	1: "not at all", 7: "very much"
RNT Process		How much do these statements apply to you at this moment?	
4.	Repetitiveness (RPT)	The same *negative* thoughts keep going through my mind again and again.	1: "not at all", 7: "very much"
5.	Intrusiveness (INTR)	*Negative* thoughts come to my mind without me wanting them to.	1: "not at all", 7: "very much"
6.	Uncontrollability (CTRL)	I get stuck on certain *negative thoughts* and can't move on.	1: "not at all", 7: "very much"
7.	Subjective burden (BUR)	*I feel weighed down by negative thoughts*	1: "not at all", 7: "very much"
RNT Content			
8.	Feelings (FEEL)	At the moment I am thinking about my feelings	1: "not at all", 7: "very much"
9.	Problems (PROB)	At the moment I am thinking about my problems	1: "not at all", 7: "very much"

Note. * this item was recoded for later analysis. Changes in wording of items to previous study highlighted in italics.

2.4. Procedure

Recruitment and baseline assessment started at the beginning of the semester (mid-October) and were completed within six weeks. During the first appointment the investigator explained the purpose and procedure of the study and participants provided informed consent. Participants were introduced to the EMA app, given the opportunity to look at all EMA items and were encouraged to ask questions if anything was unclear. Participants installed the app on their smartphone (iOS or Android). Participants not owning a smartphone received an Android smartphone for the duration of the EMA phase. Lastly, participants filled out demographic information and self-report questionnaires on trait RNT, symptom measures, and mental well-being. Participants also made an appointment for the follow-up assessment, which was set to be filled out on a specific date during the exam period at the end of their semester (M = 94.49 days, SD = 14.40 days).

The EMA phase started on the day after the first appointment and lasted for 10 days. The follow-up assessment was conducted online and comprised all questionnaires that had already been filled in at baseline. Questions regarding acceptability of the EMA paradigm were additionally included and participants were asked whether their exam period was ongoing at the time of completing the questionnaire to ensure that this criterion was fulfilled.

2.5. Statistical analysis

Statistical analyses were conducted in R (version 4.2.2.; R Core Team, 2022). The statistical analysis procedure consisted of five parts. First, we tested whether the unifactorial structure and internal consistency of the two candidate scales identified in the previous study (Rosenkranz et al., 2020) could be replicated. Model fit was estimated for both candidate scales using the same multilevel confirmatory factor analysis (MFCA) design with the R-package *lavaan* (Houben et al., 2015). This approach, as described in Huang (2017), assumes one latent factor to explain the observed variables while considering both a within-person and between-person level simultaneously in a single model. Additionally, reliability coefficients for multilevel data were calculated for the RNT scale(s). Following the generalizability theory approach by Shrout and Lane (2012), reliability of within-person changes (R_C), between-person reliability (R_{KF}), and reliability of a scale on a randomly selected day (R_{1R}) was computed.

Second, construct validity was established by investigating correlations of EMA-based RNT with baseline trait questionnaires measuring trait rumination, worry, and RNT, as well as measures of depression, anxiety, stress, and mental well-being.

Third, we tested whether known within-person dynamics between RNT, NA, and stressors could be replicated. Three multilevel models

Table 2
Descriptive Statistics of the self-report questionnaires for baseline and follow-up.

	Baseline			Follow-up				
Trait measures	*n*	*M*	*SD*	*n*	*M*	*SD*	*t*(165)	*p*
RRS-b	186	10.88	2.83	166	10.86	2.91	−0.00	>.999
PSWQ	186	47.66	10.44	166	49.33	9.66	2.43	**.016**
PTQ	186	28.76	11.51	166	28.42	11.01	−0.52	.607
Symptom measures								
GAD-7	186	6.28	3.69	166	8.51	3.97	6.75	**<.001**
PHQ-9	186	5.95	3.43	166	8.34	4.25	7.65	**<.001**
DASS-D	186	3.76	3.56	166	4.59	3.48	3.26	**.001**
DASS-A	186	2.99	2.79	166	3.63	3.00	2.84	**.005**
DASS-S	186	5.99	3.47	166	7.57	4.08	5.03	**<.001**
Mental well-being								
SWEMWBS	186	25.51	3.57	166	23.28	3.82	7.43	**<.001**

Note. RRS-b = Response Styles Questionnaire - brooding; PSWQ = Penn-State Worry Questionnaire; PTQ = Perseverative Thinking Questionnaire; GAD-7 = Generalized Anxiety Disorder Questionnaire; PHQ-9 = Patient Health Questionnaire – Depression; DASS = Depression-Anxiety-Stress-Scales, SWEMWBS = Short Warwick-Edinburgh Mental Well-Being Scale.

were calculated: (a) predicting momentary RNT (t) by NA at the preceding timepoint (t-1) while controlling for RNT the preceding timepoint (t-1); (b) predicting momentary NA (t) by RNT at the preceding timepoint (t-1) while controlling for NA at the preceding timepoint (t); (c) predicting momentary RNT at (t) by momentary negative events reported (t) after controlling for RNT at the previous moment (t-1). To investigate within-person variability, each predictor was person-mean centered. Random effects were assumed for intercept and each predictor.

Fourth, we examined the predictive validity of our EMA paradigm. Separate regression analyses were conducted to predict depression, anxiety, stress, and well-being at follow-up. We included covariates of baseline symptom severity, trait RNT (PTQ) and EMA-based RNT (i.e., average RNT score on the EMA measure). Thereby, we tested whether our EMA measure significantly predicted psychopathology over and above trait RNT.

Finally, we explored dynamic parameters in addition to person mean scores of EMA-based RNT. These parameters included stress-reactive RNT, instability, variability, and inertia of RNT. As a measure for instability, we calculated the root RMSSD for each participant, which takes into account both variability and temporal dependency over time (see Jahng et al., 2008). In line with Trull et al. (2015), we calculated participants' within-person SD from its participant-specific mean of RNT as a measure of RNT variability. Inertia was calculated as first-order autocorrelation of RNT, indicating how well RNT at each time point is predicted by RNT at the preceding timepoint (see Kuppens et al., 2010). Stress-reactive RNT was assessed by the person-specific estimates of the effect of momentary stress at timepoint t-1 on RNT at timepoint t. We investigated how these dynamic measures of RNT were associated with symptoms of depression, anxiety, stress, and well-being either at baseline or follow-up using multiple regressions. RNT inertia and RNT variability were entered in one model and their effect on the beforementioned measures was investigated. The effect of RNT instability was tested in a separate model. Likewise, the effect of stress-reactive RNT was investigated separately. In all regression models, control variables of worry (PSWQ), RRS-b, trait rumination (PTQ), and EMA-based RNT (i.e., average RNT score on the EMA measure) were included. For models predicting the symptoms at follow-up, we also controlled for the baseline symptom severity of the corresponding dependent variable. We allowed the intercepts to vary randomly across individuals (random intercept).

Table 3
Multilevel Confirmatory Factor Analysis results for the hybrid model and the process model.

χ^2	*df*	CFI	SRMR	RMSEA	90 % CI_La[a]	90 % CI_Ua[a]	*p*
a) Hybrid model: Thinking About Feelings, Thinking About Problems, Uncontrollability, Burden/Distress							
323.99 W: 293.12 B: 30.87	4	.975	.034	.139	.126	.152	<.001
b) Process model: Repetitiveness, Intrusiveness, Uncontrollability, Burden/Distress							
99.29 W: 92.20 B: 7.09	**4**	**.996**	**.010**	**.076**	**.063**	**.089**	**<.001**

Note.
CFI = Comparative-Fit Index; SRMR = Standardized Mean Square Error of Approximation; RMSEA = Root Mean Square Error of Approximation; W = within-person level; B = between-person level.
The chosen model is highlighted in bold.
[a] Lower/upper confidence interval for RMSEA $n_W = 8137$; $n_B = 186$

2.6. Transparency and openness

The current study was not preregistered. Data, analysis code, and codebook have been made publicly available at the Open Science Framework platform (OSF; https://osf.io/yuhc3/). We report all data exclusions, all manipulations, and all measures in the study. The study was approved by the local ethics committee at the Faculty of Psychology, LMU Munich.

3. Results

3.1. Data cleaning and compliance

Participants completed 9529 (87.4 %) out of 10,900 possible observations (218 participants x 10 days x 5 assessments per day). Due to technical problems, 229 observations were missing and 30 observations had to be deleted (i.e., 2.7 % of total), leaving 1112 observations missed by participants. Participants with a response rate of less than 60 % were excluded ($n = 10$). Participants with a person-level SD of 0 in at least one EMA item assessing RNT were also excluded due to implausibility ($n = 22$).

In total, 186 participants aged 18–35 years ($M = 21.18$, $SD = 3.34$, 76 % female) and 8347 observations remained for data analysis. For all analyses including the follow-up assessment, 20 participants had to be excluded as they did not fill in the follow-up during the exam period. On average, participants filled out the follow-up assessments 94.57 days ($SD = 14.44$, range: 46–131, $n = 166$) after the baseline assessment.

3.2. Descriptive data: self-report questionnaires

Descriptive statistics of self-report questionnaires are shown in Table 2 for baseline and follow-up. Questionnaires measuring RNT as a trait did not significantly change from baseline to follow-up, except for a significant increase in worry according to the PSWQ. As expected, psychopathology levels significantly increased from baseline to follow-up, while mental well-being significantly decreased.

3.3. Descriptive data: EMA

Descriptive statistics were calculated based on person-means of each EMA item and are presented in Table A1 in Supplement A. Among the 130 participants who reported having experienced negative events during the 10-day EMA period, each participant reported on average 2.53 (SD = 3.26) such events. The between- and within-person correlations between the RNT items are displayed in Table A2 in Supplement A.

Step 1: Replication of RNT Scales

MCFA results showed that the hybrid model did not yield acceptable model fit, whereas the process-related model yielded satisfactory model fit (Table 3). Based on these results, the following analyses exclusively focus on RNT as measured by the process model (in the following called EMA-based RNT [process model]).

The process model showed excellent between-person reliability of $R_{KF} > .99$ and very good within-person reliability ($R_C = .90$). Reliability for a random day was $R_{1R} = .48$.

Step 2: Construct Validity I

Positive correlations of moderate size were found between EMA-based RNT scores (process model) and trait questionnaires, as well as baseline psychopathology (Table 4). Construct validity was further reflected by a moderate negative correlation between EMA-based RNT and mental well-being.

Step 3: Construct Validity II

Multilevel analyses revealed three theoretically consistent associations between RNT and related constructs. First, a reciprocal relationship between negative affect and RNT emerged, as (a) NA at t-1significantly predicted EMA-based RNT (process model) at t when controlling for the same variable at t-1, unstandardized regression coefficient (B) = 0.11, standardized regression coefficient (β) = 0.03, SE = 0.04, 95 % confidence interval (CI) for unstandardized regression coefficient [0.03, 0.19], t = 2.69, p = .008, and (b) EMA-based RNT (process model) at t-1 significantly predicted NA at t when controlling for NA at t-1, B = 0.02, β = 0.07, SE = 0.01, 95 %CI [0.01, 0.03], t = 4.56, $p < .001$. Moreover, an association between stress and RNT was found in that (c) stressful events at t significantly predicted EMA-based RNT (process model) at t when controlling for the same variable at t-1, B = 6.80, β = 0.26, SE = 0.41, 95 %CI [6.00, 7.60], t = 16.68, $p < .001$. We further examined whether this effect remained stable after controlling for negative affect at time point t – 1. The results indicate that stressful events continued to significantly predict EMA-based RNT (process model) at time point t, even when controlling for both negative affect and prior EMA-based RNT at t – 1, B = 6.79, β = 0.26, SE = 0.41, 95 %CI [6.11, 7.70], t = 16.68, $p < .001$. These results further confirm construct validity, specifically, RNT as a response style to negative mood that in turn maintains existing NA, as well as RNT as a stress-reactive phenomenon.

Step 4: Psedictive Validity

Results of the linear regression analyses testing the effects of the person mean EMA-based RNT (process model) scores on psychopathological symptoms at both baseline and follow-up are presented in Table 5. In all models, control variables for trait RNT are included.

Depressive Symptoms. Person mean EMA-based RNT (process model) scores significantly predicted sum scores on the DASS at baseline, while controlling for trait RNT measures (PSWQ, RRS-b, and PTQ) at baseline. Person mean EMA-based RNT (process model) scores also significantly predicted depressive symptoms at the three-month follow-up, again controlling for baseline sum scores on the RNT measures (PSWQ, RRS-b, and PTQ) as well as depression (DASS) at baseline. Next to EMA-based RNT (process model), only baseline scores of the DASS-D also significantly predict depression at baseline as well as follow-up.

Anxiety Symptoms. Person mean EMA-based RNT (process model) scores significantly predicted anxiety symptoms as assessed with the DASS-A at baseline and follow-up, controlling for trait RNT measures (and baseline anxiety for analysis of anxiety symptoms at follow-up).

Stress. Person mean EMA-based RNT (process model) scores significantly predicted stress at baseline. At follow-up, no significant association between person mean EMA-based RNT (process model) and stress was evident.

Well-Being. Person mean EMA-based RNT (process model) scores significantly predicted well-being as assessed with the SWEMWBS at baseline, with higher EMA-based RNT (process model) being predictive of lower well-being. At follow-up, no significant association between person mean EMA-based RNT (process model) and well-being was evident.

3.4. Exploratory analyses

Results of exploratory analyses investigating the predictive power of dynamic RNT parameters beyond controlling for person mean EMA-based RNT (process model) and trait measures are summarized below (for details, see Supplement C in Supplementary Material).

Stress-Reactive RNT. Results of the regression models on stress-reactive RNT are shown in Table C1. Stress-reactive RNT did not significantly predict symptoms of depression or anxiety, neither at baseline nor at follow-up. Higher levels of stress-reactive RNT significantly predicted higher levels of stress at baseline. Furthermore, higher stress-reactive RNT significantly predicted lower well-being at baseline.

RNT Instability. Results on RNT instability are shown in Table C2.

Table 4
Correlations between EMA-based RNT, trait measures, and symptom measures (N = 166).

	Process Model RNT		
Variable name	r	[95 % CI]	p
Trait Measures			
RRS-b	.25	[.11, .39]	**<.001**
PSWQ	.42	[.29, .54]	**<.001**
PTQ	.44	[.31, .55]	**<.001**
Psychopathology			
GAD-7	.48	[.35, .59]	**<.001**
PHQ-9	.41	[.27, .53]	**<.001**
DASS-D	.43	[.30, .55]	**<.001**
DASS-A	.36	[.22, .49]	**<.001**
DASS-S	.46	[.33, .57]	**<.001**
Mental well-being			
SWEMWBS	−.44	[-.56, −.31]	**<.001**

Note.
Process Model RNT = EMA-based process model of RNT, EMA = ecological momentary assessment, RNT = repetitive negative thinking, RRS-b = Response Styles Questionnaire - brooding; PSWQ = Penn-State Worry Questionnaire; PTQ = Perseverative Thinking Questionnaire; GAD-7 = Generalized Anxiety Disorder Questionnaire; PHQ-9 = Patient Health Questionnaire – Depression; DASS = Depression-Anxiety-Stress-Scales; SWEMWBS = Short Warwick-Edinburgh Mental Well-Being Scale.

Table 5
Linear regression models predicting psychopathological symptoms (N = 166).

Dependent Variables	DASS-D			DASS-A			DASS-S			SWMBWS		
Predictor	*B* [95 % CI]	β	*p*	*B* [95 % CI]	β	*p*	*B* [95 % CI]	β	*p*	*B* [95 % CI]	β	*p*
Dependent Variables at Baseline												
Process Model RNT (av)	0.30 [0.14–0.46]	0.28	**<.001**	0.15 [0.02, 0.28]	0.17	**.023**	0.29 [0.14, 0.44]	0.27	**<.001**	−0.22 [-0.37, −0.08]	−0.21	**.003**
PSWQ at BL	0.02 [0.14, 0.46]	0.07	.465	0.07 [0.02, 0.12]	0.25	**.008**	0.01 [0.04, 0.15]	0.29	**.001**	−0.15 [-0.21, −0.10]	−0.45	**<.001**
RRS-b at BL	0.27 [-0.04, 0.08]	0.22	**.006**	0.18 [0.03, 0.34]	0.19	**.021**	0.20 [0.02, 0.38]	0.16	**.034**	−0.11 [-0.28, 0.07]	−0.09	.222
PTQ at BL	0.05 [0.08, 0.47]	0.15	.113	0.02 [-0.02, 0.07]	0.09	.330	0.02 [-0.03, 0.07]	0.06	.498	−0.01 [-0.07, 0.04]	−0.05	.567
Dependent Variables at Follow-Up												
Process Model RNT (av)	0.23 [0.06, 0.41]	0.21	**.010**	0.21 [0.07, 0.35]	0.23	**.004**	0.11 [-0.11, 0.33]	0.09	.311	−0.16 [-0.36, 0.04]	−0.13	.118
PSWQ at BL	0.02 [-0.03, 0.08]	0.08	.412	0.05 [-0.01, 0.10]	0.16	.090	0.02 [-0.06, 0.10]	0.05	.654	0.05 [-0.03, 0.13]	0.14	.206
RRS-b at BL	0.05 [-0.16, 0.26]	0.04	.629	0.04 [-0.13, 0.21]	0.03	.674	−0.00 [-0.25, 0.25]	−0.00	.991	−0.13 [-0.36, 0.11]	−0.09	.281
PTQ at BL	−0.03 [-0.09, 0.04]	−0.08	.427	−0.06 [-0.11, −0.01]	−0.22	**.018**	0.04 [-0.04, 0.11]	0.10	.326	−0.06 [-0.13, 0.01]	−0.18	.083
DV at BL	0.33 [0.17, 0.49]	0.33	**<.001**	0.44 [0.27, 0.60]	0.41	**<.001**	0.30 [0.09, 0.51]	0.25	**.006**	0.28 [0.07, 0.48]	0.25	**.009**
Model Parameter												
$R^2_{adj.}$ BL/FU	.282/.215			.276/.278			.349/.131			.414/.144		

Note. DV = dependent variable; *B* [CI] = unstandardized regression coefficient [with 95 % confidence interval], β = standardized regression coefficient, *p* = *p*-value; *N* = observations used for analyses; $R^2_{adj.}$ = adjusted coefficient of determination; BL = baseline; FU = 3-month follow-up; Process Model RNT (av) = Average sum score on the EMA-based process model of RNT across all completed measurement timepoints; RRS-b = Response Styles Questionnaire - brooding; PSWQ = Penn-State Worry Questionnaire; PTQ = Perseverative Thinking Questionnaire; GAD-7 = Generalized Anxiety Disorder Questionnaire; PHQ-9 = Patient Health Questionnaire – Depression; DASS-D = Depression Subscale of the Depression-Anxiety-Stress-Scales; DASS-A = Anxiety Subscale of the Depression-Anxiety-Stress-Scales; DASS-S = Stress Subscale of the Depression-Anxiety-Stress-Scales; SWEMWBS = Short Warwick-Edinburgh Mental Well-Being Scale.

The linear regression analyses showed that RNT instability significantly predicted depressive symptoms at follow-up, with higher RNT instability being predictive of higher depressive symptoms. For symptoms of anxiety, neither a significant effect of RNT instability at baseline nor at follow-up could be shown. Regarding symptoms of stress, higher RNT instability significantly predicted higher levels of stress at baseline and follow-up. Lastly, higher RNT instability significantly predicted lower well-being at baseline.

RNT Inertia and RNT Variability. Results on the effect of RNT inertia and RNT variability on psychopathology are shown in Table C3. Neither depressive symptoms nor symptoms of anxiety were significantly predicted by RNT inertia. However, RNT variability significantly predicted symptoms of anxiety and depression at follow-up, with higher variability being predictive of higher symptoms. In the analyses on levels of stress, only RNT inertia significantly predicted stress symptoms at baseline, with higher inertia predicting lower levels of stress. Conversely, only RNT variability significantly predicted stress symptoms at follow-up, with higher variability predicting higher levels of stress. Well-being at baseline was significantly predicted by RNT variability, with lower RNT variability being predictive of higher well-being. RNT inertia did not predict the level of well-being at either timepoint.

4. Discussion

The primary aim of this study was to cross-validate the EMA paradigm developed by Rosenkranz et al. (2020) measuring RNT in daily life. The authors recommended two different scales for further evaluation, namely a process-based scale comprising items on the repetitiveness, intrusiveness, uncontrollability, and burden of RNT on the one hand, and a hybrid scale combining content-based and process-based items. In the current study, only the process-based model showed an adequate model fit, whereas the hybrid model was not well-explained by the data. Therefore, further analyses were conducted on the process-based model. As in Rosenkranz et al. (2020), the process-based measure showed high reliability as well as high concurrent validity, indicated by moderate correlations with trait RNT and symptom measures.

Extending earlier findings, the validity of this EMA-based process-focused measures of RNT was tested in two ways. First, theory and earlier empirical findings predict that RNT in daily life should be dynamically related to negative affect and stressors. Thus, confirming these predicted associations in our EMA assessment period would furthermore strengthen the construct validity of the measure. Consistent with our predictions, higher NA at preceding assessments significantly predicted increases in RNT at current assessments, and vice versa. Moreover, RNT increased significantly in response to stressors, even when controlling for RNT at the preceding assessment.

Second, our longitudinal design allowed testing whether RNT in daily life assessed via EMA predicts future levels of psychopathology in response to stressors. We conducted the baseline assessment at the beginning of the semester with a subsequent follow-up assessment during the exam period at the end of the semester approximately 3 months later. Results showed that person-mean RNT scores assessed via EMA at baseline significantly predicted symptoms of depression and anxiety assessed during the exam period at follow-up, while controlling for baseline symptom levels of depression or anxiety, respectively, as well as three trait RNT questionnaire scores assessed at baseline. Of note, the EMA-based RNT measure not only continued to predict future psychopathology when trait questionnaire measures of RNT were controlled but even outperformed these measures that showed either no predictive power (in the case of depression) or lower predictive power than EMA-based RNT (in the case of anxiety symptoms) in the regression analyses. This strongly supports the validity of assessing RNT in daily life using EMA.

Interestingly, RNT only predicted anxiety and depression during the exam period, but not levels of stress or well-being. This finding may reflect important differences in the specificity of these constructs. While anxiety and depression are specific symptom dimensions that have also demonstrated close connection to RNT in earlier research (see Ehring & Watkins, 2008; Watkins & Roberts, 2020), perceived stress and well-being can be considered broad and context-dependent,

encompassing a wide range of environmental, social, and intrapersonal influences (Cohen et al., 1983; Zhang et al., 2024). As such, it may contain substantial variability that is not explained by levels of RNT, but rather by external situational factors (e.g., workload, interpersonal conflicts). Future research should continue to systematically investigate how RNT as assessed via EMA relates to other mental health problems. Thereby, the potential transdiagnostic role of daily-life RNT and its association to different domains of psychological functioning could be further investigated.

The current findings are not only in line with Rosenkranz et al. (2020) but also with recent findings by Funk et al. (2025) who also found a high predictive power of RNT assessed via EMA on future levels of psychopathology over and above trait RNT measures. However, whereas in the Funk et al. (2025) study trait RNT questionnaires were exclusively content-focused, the current study additionally controlled for trait PTQ scores, which is also a process-focused instrument, further strengthening the findings.

In addition to focusing on average RNT scores per person, we also conducted exploratory analyses testing whether dynamic features of RNT (stress-reactive rumination, instability, variability, and inertia) are additionally predictive of psychopathology. While previous research questioned the added value of dynamic parameters over average levels of emotions (Dejonckheere et al., 2019), the current study showed that RNT variability was predictive for three of the mental health-related measures at follow-up (depression, anxiety, and stress) and for well-being at baseline, when controlling for person-level average RNT assessed via EMA. RNT inertia only predicted stress at baseline and stress-reactive RNT was not predictive at all.

The predictive utility of RNT variability for a range of psychopathological symptoms aligns largely with previous findings (Bean & Ciesla, 2024; Funk et al., 2025). According to Bean and Ciesla (2024), it may be that individuals with high ruminative variability are more likely to experience intense, affect-driven or stress-related rumination episodes. Given that stress-reactive RNT was not a significant predictor of psychopathology in our data, these abrupt changes in RNT may be more closely linked to other factors, such as mood dynamics, rather than situational stress alone.

In summary, these exploratory findings may suggest that assessing dynamic patterns of RNT in addition to average levels may help to identify dysfunctional patterns of RNT. However, reflecting upon findings reported by Funk et al. (2025), who assessed all three parameters (i.e., variability, inertia, and instability), the current results do not replicate previous findings. Thus, so far results for dynamic parameters are much less consistent than for average EMA-based RNT scores. One reasons for this could be that the dynamic parameters are influenced to a much higher degree by methodological factors including time between assessments, participant compliance, and item wordings.

Our study showed a number of important strengths, including the high compliance rates and the use of a prospective design including a follow-up assessment conducted in a period of increased stress. On the other hand, several limitations are noteworthy. First, we investigated a non-clinical student sample with overall low levels of psychopathology. Future research should replicate findings in clinical or at-risk samples. Second, the exploratory analyses included a large number of tests, suggesting that the findings need to be interpreted with utmost caution. Finally, participants received incentives for participation and compliance, which may limit the generalizability to situations where this is not the case.

4.1. Constraints on generality

The current study recruited university students in Germany, and individuals currently suffering severe mental health problems were excluded. Therefore, it remains to be shown whether findings replicate in samples with higher levels of both RNT and psychopathology. Although RNT is typically conceptualized as a continuous phenomenon (e.g., Watkins & Roberts, 2020), ranging from non-clinical and subclinical to clinical levels, it can not be ruled out that an EMA-based assessment of RNT shows different characteristics depending on severity. In addition, although no data on ethnic background, immigration history, or socioeconomic status was collected, the population the sample was drawn from can be described as young, westernized, educated, and showing moderate to high socio-economic status. Thus, cross-validation of the findings in more diverse cultural, ethnic and socio-economic contexts appears necessary. Additionally, the stressor (i.e., exam period) may not be representative of the types of chronic, unpredictable, or socially embedded stressors often implicated in clinical populations. More specifically, the exam period is time-limited and predictable, which may constrain the applicability of our findings to other contexts. Lastly, although follow-up assessments were conducted within this designated stress period, participants completed them at varying time points during the exam period. While this variability reflects real-life conditions and may enhance ecological validity, it introduces some variability in the intensity of the stressor. In summary, future research should seek to replicate these findings in more diverse, at-risk, and clinical populations, while also considering other stress-related contexts.

5. Conclusion

In conclusion, the current findings strongly support the added value of assessing RNT in daily life using EMA over and above traditional trait questionnaire measures. It appears recommendable for future research into the role of RNT in psychopathology to consider using EMA-based RNT assessments in addition to questionnaires. If the current findings hold up in clinical populations and the EMA-based assessment is also found to be sensitive to change, it may also be promising to use the EMA-based assessment of RNT as outcome variables in clinical trial research in order to more closely assess treatment effects on individuals' daily lives.

CRediT authorship contribution statement

Celina L. Müller: Writing – original draft, Formal analysis, Data curation. **Tabea Rosenkranz:** Writing – original draft, Project administration, Methodology, Conceptualization. **Anika Schiller:** Writing – review & editing, Data curation. **Keisuke Takano:** Writing – review & editing, Methodology, Formal analysis. **Edward R. Watkins:** Writing – review & editing, Funding acquisition, Conceptualization. **Andreas Mühlberger:** Writing – review & editing, Supervision. **Julia Funk:** Writing – review & editing, Formal analysis, Data curation. **Thomas Ehring:** Writing – review & editing, Supervision, Project administration, Investigation, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors have nothing to declare.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.brat.2025.104830.

Data availability

The data will be made open. I have shared the link to my data in the manuscript.

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