Getting the blues: negative affect dynamics mediate the within-person association of maladaptive emotion regulation and depression

Levente Rónai ^{a1}, Bertalan Polner ^a

^a Faculty of Natural Sciences, Department of Cognitive Science, Budapest University of Technology and Economics

¹Corresponding author: Levente Rónai, Budapest 1111, Egry József street 1., T building, V. floor 506, telephone + 36 1 463 1273, fax: +36 1 463-1072
e-mail: ronai.levente@ttk.bme.hu

Data and code are publicly available via Open Science Framework and can be accessed via the following URL: <https://osf.io/vz3qc/>

Abstract

Temporal patterns of affective functioning such as emotional inertia and instability may predict increases in depressive symptoms. However, the investigation of maladaptive emotion regulation's role in affect dynamics and depressive symptoms at the within-individual level is still lacking. We collected intensive longitudinal data regarding momentary maladaptive emotion regulation strategies (rumination and expressive suppression) and negative affective states (NA) (measured multiple times a day), perceived stressors and depressive symptoms (measured every three days) from a general population sample during the COVID-19 pandemic's first wave in Hungary. The final dataset included 7117 affective states surveys from 125 participants, which were aggregated in 460 three-day measurement windows. Multilevel SEM models were fit to test whether affect dynamics mediate the association between maladaptive emotion regulation strategies, negative affect intensity, and two domains of depression, anhedonia, and negative mood and thoughts. Within and between individuals, rumination indirectly predicted NA intensity and negative mood and thoughts through elevated NA instability and NA inertia. Expressive suppression had a negative indirect effect on NA intensity via NA inertia at the within-person level, while this mediation effect was positive at the between-person level. Moreover, affect dynamics were positively connected to depressive symptoms and these associations were mediated by NA intensity. These suggest that disturbances in emotion regulation are indirectly connected to depressive symptoms, mediated by specific temporal patterns in affective functioning. These findings hold both at the within- and the between-individual level. Our findings may facilitate automated depression risk assessment based on simple affective and emotion regulation time series.

Keywords: affect dynamics, emotion regulation, depression, stressors, experience sampling method

1. Introduction

Major depressive disorder is a mood-related psychiatric disorder with two core symptoms: depressive mood (long-lasting negative emotions and thoughts) and anhedonia (loss of interest or pleasure) (Kennedy, 2008). Affect dynamics, such as emotional inertia and instability, are thought to be indicators of disrupted affective functioning and may predict the emergence of affective disorders (Trull et al., 2015). Higher emotional inertia refers to rigid and inflexible affective states that remain relatively unchanged within a certain time period, regardless of changes in the environment (Koval et al., 2015a; Kuppens et al., 2010), and inertia is typically represented by the autocorrelation in time series data (Koval et al., 2012; Kuppens et al., 2012, 2010). In contrast to inertia, emotional instability refers to recurrent and rapidly alternating ups and downs in emotion states that can be indicated by the root mean square successive difference (RMSSD) of consecutive affective states (Jahng et al., 2008; Thompson et al., 2012; Trull et al., 2015).

The examination of affect dynamics requires intensive time-series data that can be collected with the Experience Sampling Method (ESM) (Csikszentmihalyi and Larson, 2014; Myin-Germeys et al., 2018, 2009). Main advantages of the ESM include higher ecological validity and reduced recall bias, relative to traditional cross-sectional questionnaires. Furthermore, affect dynamics provide insight into temporal patterns in mental experiences that participants themselves may not be aware of (Sperry and Kwapil, 2020).

Importantly, dynamics of negative affect (NA) predict symptom severity of depression: inertia and variability of NA elevate before worsening of depressive symptoms in healthy and clinically depressed individuals as well (Brose et al., 2015; van de Leemput et al., 2014; Wichers et al., 2016). Also, increased levels of instability of NA were observed in depressed individuals, as compared to healthy controls (Thompson et al., 2012). However, another study pointed out that inert affective states predict concurrent but not future depression (Schreuder et

al., 2020), questioning the predictive utility of this indicator. Moreover, most of the literature is limited in that they evaluated the relationship of affect dynamics with depression levels that were measured before and/or long after the ESM assessment (Brose et al., 2015; Schreuder et al., 2020; Sperry et al., 2020). Therefore, little is known about the within-person associations between affect dynamics and depressive symptoms (see Wichers et al., 2020, 2016), which would be essential for the real-time assessment of depression risk.

Emotional inertia and instability may be a consequence of maladaptive emotion regulation such as rumination and expressive suppression. Emotion regulation refers to mechanisms and strategies that aim to control emotions (McRae and Gross, 2020), and the above-mentioned strategies are maladaptive in that they typically fail to downregulate negative affect (for a review see Colombo et al., 2020). Rumination, persistently focusing on one's feelings, can prevent one from recovering from a negative affective state by amplifying stress responses, decreasing access to positively valenced mental content, impairing problem solving and proactive behavior, and reducing social support (Nolen-Hoeksema et al., 2008). Indeed, the states of being 'stuck' affectively (NA inertia) and cognitively (ruminative thinking) are associated with each other yet they independently predict depressive symptom severity at the between-person level (Koval et al., 2012). Additionally, rumination may also increase emotional instability by amplifying reactivity to stressors (Genet and Siemer, 2012).

Less data is available on expressive suppression, which refers to the conscious inhibition of the behavioral expression of emotions (Gross, 2015; McRae and Gross, 2020). Ironically, expressive suppression may intensify negative emotions (Daghighi et al., 2009), and indeed, according to ESM studies, expressive suppression was positively related to momentary elevation in negative affective states (Brans et al., 2013; Brockman et al., 2017). In terms of affect dynamics, inertia of NA also showed trait-level associations with expressive suppression of negative emotions (Koval et al., 2015b). It has been argued that habitual

expressive suppression reduces the repertoire of behavioral expression but not the inner experience of negative emotions, and this can contribute to inflexible, inert affective functioning (Koval et al., 2015b). Furthermore, suppressing negative mental content may lead to more intense negative mood through more unstable negative affect: by suppression, one may successfully downregulate negative emotions at a particular moment by counteracting them with more pleasant mental contents; however, paradoxically, generally elevated negative mood can be further maintained over a longer period, especially if one is under mental load (Dalglish et al., 2009; Wegner, 1994).

During the COVID-19 pandemic, the prevalence of depression has increased dramatically, as compared to pre-pandemic times (Ettman et al., 2020); hence, this period has provided a unique opportunity to examine the development of depressive symptoms during a crisis. To date, a few studies have revealed the temporal impact of the COVID-19 pandemic on affective functioning (Alessandri et al., 2020; Martín-Brufau et al., 2020) and sleep disturbances (Simor et al., 2021). Moreover, external stressful events, affect dynamics and depression might be interrelated: inertia of negative affective states can also occur due to the prolonged presence of stressors (Koval et al., 2015a, 2013) that also show a close relationship with increased symptom severity of depression (Beck and Bredemeier, 2016; Ettman et al., 2020). So, adjusting for the effect of stressful external events is essential when examining the specific association of dynamic affective indicators with depressive symptoms. By filling this knowledge gap, our aim is to improve understanding of how depression evolves and also to facilitate the prediction of depression risk.

Here, for the first time, we test whether emotion regulation and affect dynamics predict - either directly or indirectly - within-person changes in severity of depressive symptoms within measurement windows of a few days during an extremely stressful period. According to a line of findings, the complex temporal information carried by affect dynamics positively predicted

depressive symptoms assessed earlier and later, since affect dynamics specifically reflect problems with emotion regulation (Koval et al., 2012; Schreuder et al., 2020; Thompson et al., 2012; Trull et al., 2015; Wichers et al., 2016). Still, as the existing literature relies largely on cross-sectional assessments of depression, we cannot draw conclusions regarding the within-individual relationships between emotion regulation strategies, affect dynamics and depressive symptoms (Fisher et al., 2018). Furthermore, characterizing temporal processes and contextual factors influencing fluctuations in psychopathological states is essential to get a detailed and complex picture of neuropsychiatric phenomena (Gillan and Rutledge, 2021; Hitchcock et al., 2022). Therefore, in the present study, we evaluate the utility of distinct emotion regulation strategies (rumination and expressive suppression) and affect dynamics in predicting within-person changes in depressive symptoms, while accounting for stressor-exposure. We collected intensive time-series data in the general population during the first wave of the COVID-19 pandemic, when individuals were likely to be exposed to economic, social and health-related stressors, putting them at increased risk of developing depression.

2. Methods

2.1. Participants and screening

Hungarian-speaking adult participants from the general population were recruited through calls posted on social media and press releases. Our study had two main phases (cross-sectional baseline and ESM phases, see Materials and Procedure for more details): the cross-sectional baseline assessment was completed by 304 participants ($N[\text{females}] = 239$, $\text{Mean}[\text{age}] = 37.87$ years, $\text{SD}[\text{age}] = 12.96$, $\text{Min}[\text{age}] = 18$, $\text{Max}[\text{age}] = 82$). Then, 282 individuals decided to enter the study's second phase that included the ESM assessments.

To ensure the validity of the responses, we excluded participants with too fast responses on the baseline assessment (< 7 minutes; Median after screening = 12.83 minutes). We also

filtered data from ESM surveys that were completed by the participants too quickly (< 30 seconds) or too slowly (> 10 minutes) (Median after screening = 56 seconds). Moreover, we excluded participants and measurement windows within participants with a higher number of missing data. More specifically, we retained only those three-day measurement blocks in which a certain participant had completed the survey on depressive symptoms and stressors and also responded to at least five consecutive surveys on affective states and emotion regulation (Median = 9, Obs. Max = 19, Theor. Max = 21) on affective states (the latter were the part of the ESM phase of the study, see Materials and Procedure for more detail). Finally, we kept three-day measurement blocks with at least 0.1 mean standard deviation of the NA states. We applied these exclusion criteria as the validity of data and the sufficient number of consecutive responses are necessary to calculate reliable metrics of affect dynamics.

After data screening, 125 individuals were included in the final analyses, who completed a total of 7117 surveys on affective states (per person: Median = 43, Obs. Range = 10-175, Theor. Range = 0-224) and 460 surveys on stressors and depressive symptoms (Median = 3, Obs. Range = 1-9, Theor. Range = 0-9). In order to evaluate whether the screening of participants introduced any sampling bias, we compared the final and the initial sample (see Table 1). The final sample significantly differed from those that were screened out in terms of sex ratio (78.6% vs. 85.6% women), while no significant differences emerged regarding age, education, or depression and stress exposure at baseline. Comparison of the samples is reported in Table 1.

Table 1. Demographic and baseline characteristics of study samples

	Initial sample	ESM		
		Not included	Final	Comparison (Not included vs. Final)
Size	304	179	125	
Age				$U = 12485$, $p = 0.09$
Mean	37.87	36.63	39.64	
Median	35	35	37	
SD	12.96	12.13	13.93	
Range	18 - 82	18 - 82	19 - 73	
Gender				$\chi^2(2) = 8.35$, $p = 0.02^*$
Female % (N)	78.62 % (239)	73.74 % (132)	85.6% (107)	
Male % (N)	21.05 % (64)	26.26 % (47)	13.6% (17)	
Other % (N)	0.33 % (1)	0 % (0)	0.8% (1)	
Education				$\chi^2(5) = 4.35$, $p = 0.49$
Primary school degree % (N)	0.66 % (2)	1.12 % (1)	0 % (0)	
Less than high school diploma % (N)	0 % (0)	0 % (0)	0 % (0)	
High school degree or equivalent % (N)	1.97% (6)	2.23 % (3)	1.6 % (2)	
Bachelor's degree % (N)	21.05 % (64)	22.35 % (40)	19.2 % (24)	
Master's degree % (N)	67.11 % (204)	66.48 % (119)	68 % (85)	
Doctorate (PhD) % (N)	6.25 % (19)	4.47 % (8)	8.8 % (11)	
Other % (N)	2.96 % (9)	3.35 % (6)	2.4 % (3)	
Baseline Depression				$U = 7019.5$, $p = 0.52$
Mean	18.97	19.63	18.33	
Median	17	17	16.5	
SD	13.22	13.69	12.78	
Range	0-51	0-48	0-51	
Baseline Stress-exposure				$U = 7527$, $p = 0.78$
Mean	1.73	1.73	1.73	
Median	2	1	2	
SD	1.36	1.41	1.31	
Range	0-6	0-6	0-6	

* $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

Table 1. Demographics and baseline descriptive statistics of the initial and the final sample. The reduction in sample size was due to attrition and data quality control measures (too fast responses on baseline survey, high number of missing ESM data, lack of consecutive ESM responses, lack of variance in negative affect, see Participants and Screening section for more detailed information). Comparisons did not indicate significant introduction of bias in terms of demographics, baseline depressive symptoms, or stressor exposure, except for a 12% increase in the ratio of women.

2.2. Data Collection Period

Data collection lasted from May 18th until July 28th, 2020, which overlapped with the period of the first wave of the COVID-19 pandemic in Hungary (from March until June 2020). In the framework of the state of emergency, serious epidemic measures such as closure of educational institutions, restricted opening hours of shops, and curfew were introduced by the Hungarian government in March 2020. A significant proportion of these measures were in place until the end of the emergency (June 18th, 2020). However, social and economic stressors, such as the steady rise in unemployment, continued to be present after the first wave (Köllő, 2020). Hence, data collection occurred during a period which was stressful in various ways.

2.3. Materials and Procedure

We designed an online ESM study and collected time-series data with a web-based application called formr.org (Arslan et al., 2020). Formr.org allows individuals to participate in studies via digital tools by opening invitation links that are sent to their email addresses (Arslan et al., 2020). In the first, cross-sectional phase of our study, participants were asked to complete questionnaires regarding demographics and various trait-level constructs (which we do not analyze in the present study) and could indicate if they had any persistent psychiatric disorder. At the end of this module, participants could decide to enter the ESM phase that would start the next day. In this part, participants received surveys eight times every day (in every second hour, from 08:00 AM until 10:00 PM) that included seven-point (1 = ‘Not at all’; 7 = ‘Completely’) Likert-items about momentary positive (cheerful, enthusiastic, calm, active), and negative affective states (sad, afraid, irritated, angry, distracted). All items were selected based on the dimensional model of emotions (axes of arousal and valence; (Russell, 2003) and previous studies (Brans et al., 2013; Bringmann et al., 2016; Wichers et al., 2016)

This survey also encompassed six 6-point (1 = ‘Not at all’; 6 = ‘Completely’) Likert-items regarding distinct emotion regulation strategies, based on an earlier ESM study (Brans et al., 2013); ‘In the last two hours...’ and continued with ‘I have calmly reflected on my feelings’ (reflection), ‘I have changed the way I think about what causes my feelings’ (reappraisal), ‘I have talked about my feelings with others’ (social sharing), ‘I have engaged in activities to distract myself from my feelings’ (distraction), ‘I have avoided expressing my emotions’ (expressive suppression), and ‘I couldn’t stop thinking about my feelings’ (rumination). In the present study, we analyze only maladaptive emotion regulation techniques as expressive suppression and rumination. Originally, we planned to include reappraisal as well, but we decided not to do so as feedback from participants indicated that the reappraisal item was not well understood. Our focus on maladaptive emotion regulation strategies is motivated by the conjecture that they are causally related to affect dynamics (Koval et al., 2015b, 2012; Kuppens and Verduyn, 2017).

To evaluate depressive symptoms and stressor-exposure, participants were asked to complete another battery every third day. Depressive symptoms experienced during the previous three days were measured with the depression subscale of the Symptom Checklist-90-Revised (SCL-90-R; Derogatis and Savitz, 1999). These batteries also included a survey that we created to collect data on financial, health-related or social stressors (12 items, e.g., job loss, conflicts at work or with significant others, problems with paying bills) and support and environmental resources (9 items, e.g., new job, increasing salary, improvement in health, not analyzed here) over the previous three days (see Supplementary Materials for further details). Participants could respond to depression and stressor surveys between 6 PM and 10 PM every third day. After completing depression and stressor surveys, participants did not receive more surveys on that day (the study continued next morning with the affective states survey).

Depressive symptoms and stressor survey was also included at the end of the cross-sectional phase, in order to examine baseline depression and exposure to stressors.

The ESM phase lasted for a maximum of 28 days; however, participants could quit the study any time. After finishing the study, in return for their time and effort, if they requested, participants received feedback in an email containing figures that showed daily changes of their affective state levels. The study design is shown in Figure 1.

Figure 1. *Design of the study*

Figure 1. When participants finished the cross-sectional part of the study (I. phase), the next morning they could enter the longitudinal part (II. phase). This part was characterized by three-day blocks of surveys: depression and stressor surveys were opened for participants every third day evening, while surveys on affective states were sent every day in every second hour. After completing a depression and stressor survey, participants did not receive more surveys that day and the cycle started again the next day morning with affective states surveys. Participants could quit the study anytime (III. phase). After quitting the study, participants received a feedback email (if they requested) about the daily changes of their affective state levels.

2.4. Data Analysis

Analyses were performed in R (version: 3.6.1; R Core Team, 2019) using R studio (version: 1.3.1093; RStudio Team, 2019). Codes and processed data to reproduce the analyses are provided here: <https://osf.io/vz3qc/>.

2.4.1. Computation of negative affect (NA) scores

First, we conducted parallel analysis in order to determine the number of components defining momentary positive and negative affective states. Parallel analysis suggested two components and principal component analysis (with oblimin rotation) yielded a negative (NA) and a positive affective (PA) component (variance explained: 35% and 32%, for NA and PA, respectively, component correlation: $r = -0.34$, $\chi^2 = 8183.87$, RMSR = 0.08, Fit = 0.96) (see Supplementary Materials Table S1 for further details). In subsequent analyses, we used the scores of the NA component to calculate affect dynamics.

2.4.2. Factor structure of SCL-90-R depression subscale

We analyzed the structure of the SCL-90-R depression subscale with multilevel confirmatory factor analysis (lavaan R package, version 0.6-9, Rosseel, 2012). Indices of a one-factor model showed questionable fit ($\chi^2(130) = 417.853$, $p < 0.001$, CFI = 0.86, TLI = 0.83, RMSEA = 0.07, SRMR[within-person] = 0.06, SRMR[between-person] = 0.07). Modification indices suggested large improvement of fit if residual covariances between three items related to anhedonia (eg. reduced energy, lack of interest, things taking extra effort) were included. Therefore, we also fitted a correlated two-factor model with factors of anhedonia (with loading for three items with high residual covariances from the previous, one-factor model) and negative mood and thoughts (ten items regarding hopelessness, self-blame, worry, and feeling lonely); note that these parallel the two core symptoms of depression (Kennedy, 2008). This modified model had convincing fit indices ($\chi^2(128) = 249.302$, $p < 0.001$, CFI = 0.94, TLI = 0.93, RMSEA = 0.045, SRMR[within-person] = 0.046, SRMR[between-person] = 0.055) (see factor loadings and correlations in Supplementary Materials Table S2). In further analyses, we used multilevel factor scores of anhedonia and negative mood and thoughts as defined in this model. Reliability of these factors were acceptable at the within-person level and excellent at

the between-person level (negative mood and thoughts: $\omega[\text{within-person}] = 0.75$, $\omega[\text{between-person}] = 0.95$; anhedonia: $\omega[\text{within-person}] = 0.71$, $\omega[\text{between-person}] = 0.95$).

2.4.3. Computation of affect dynamics and emotion regulation in three-day blocks

To capture emotional inertia in three-day measurement blocks, hierarchical autoregressive modeling was applied for the calculation of the statistical relationship between NA component scores at consecutive time points (R package lme4, version 1.1-25, Bates et al., 2015). We fitted a multilevel autoregressive model where NA level was the dependent variable and lagged NA level (within-person centered) was the predictor. We detrended the model by including the dates of depressive symptoms and stressor surveys and daily beeps in the models as predictors. We included a random slope for lagged NA and intercept nested in three-day blocks - corresponding to depression and stressor surveys - that were nested within participants. From the strength of the statistical relationship between consecutively measured NA's (autoregressive random effects), we could infer the temporal dependency between these time points: this can be considered an indicator of inertia of NA for a given three-day block for a given participant, relative to the participant's typical level of inertia. We extracted individual random slopes between consecutive affective states that were nested in three-day measurement blocks within individuals and used these random slopes as within-person indicators of inertia. Autoregression effects reflecting differences between participants were also obtained from this model.

With respect to affective instability in three-day measurement blocks of NA, we calculated the root mean square successive difference (RMSSD). This metric encompasses the root of the average squared differences between consecutive affective states. Just as in the case of emotional inertia, we computed RMSSDs (as affective instability) of NA component scores

for three-day-blocks. We also computed the three-day mean levels of NA (NA intensity), rumination and expressive suppression.

2.4.4. Exploring mediation effects between affect dynamics, emotion regulation and depression using multilevel SEM

Our aim was to investigate the complex relationships of emotion regulation strategies, affect dynamics, exposure to stressors and depressive symptoms. Therefore, we fitted multilevel SEM models (structural equation model; R package lavaan, version 0.6-9, Rosseel, 2012) in order to explore the direct and indirect effects of rumination and expressive suppression on NA intensity and the two factors of depression, potentially mediated by affect dynamics.

We estimated the model on two levels: at the within-person level, we adjusted for the effects of exposure to stressors and the count of depression and stressor surveys (as time-variant, detrending variable) on NA inertia and instability, on NA intensity and on negative mood and thoughts/anhedonia. At the between-person level, the effects of age, gender and exposure to stressors (as time-invariant control variables) on NA dynamics, NA intensity and depressive symptoms were adjusted for. At both levels, three-day mean levels of rumination and expressive suppression were entered into the SEM models as predictors. Note that at the within-person level, associations between deviations from a person's typical level during a three-day-block are captured: e.g., did a person demonstrate more inertia between 20 and 22 May 2020 to Wednesday than their average, if this person ruminated more during these three days, then they typically did during the study? While at the between-person level, we can examine questions regarding the typical levels of individuals: e.g., over the course of the study, do people who ruminate more also tend to show higher levels of inertia? For both levels, we included additional paths between NA inertia and instability as predictors, NA intensity as

mediator and the two factors of depression as outcomes. Covariances were included in the model between expressive suppression and rumination, between affect dynamics, and also between factors of depression, respectively.

3. Results

3.1. Compliance and descriptive statistics

The compliance rate of affective states surveys in the final sample of 125 participants was appropriate (Median = 60.9%, Min = 41.7%, Max = 85.4%). The descriptive statistics of the final sample can be seen in Table 2.

Table 2. *Descriptive statistics of emotion regulation, depression and exposure to stressors results in the final sample in the ESM phase*

	Mean	Median	SD	Obs. Range	Theor. Range
Exposure to Stress	1.06	1	1.16	0-7	0-12
Depression*					
SCL-90 subscale Total	16.26	14	12.32	0-48	0-52
Anhedonia	4.65	4	3.63	0-12	0-12
Negative Thoughts and Feelings	11.61	9	9.65	0-37	0-40
Emotion Regulation					
Reappraisal*	1.67	1	1.17	1-6	1-6
Distraction*	2.59	1	1.91	1-6	1-6
Reflection*	2.33	2	1.53	1-6	1-6
Social Sharing*	2.02	1	1.57	1-6	1-6
Rumination	1.65	1	1.22	1-6	1-6
Expressive Suppression	2.53	1	1.89	1-6	1-6

*We report these scores for comparability, we have not used these metrics in our models

3.2. Multilevel SEM models for emotion regulation, affect dynamics and depression

We fitted multilevel SEM models to investigate how emotion regulation strategies, affect dynamics and depressive symptoms are interrelated. In our model, emotion regulation strategies (rumination and expressive suppression), affect dynamics (NA inertia and instability) and NA intensity as well as depressive symptoms (anhedonia and negative mood and thoughts) were included. Indices of the multilevel SEM model showed appropriate fit($\chi^2(312) = 594.771$, $p < 0.001$, CFI = 0.91, TLI = 0.89, RMSEA = 0.04, SRMR[within-person] = 0.05, SRMR[between-person] = 0.07). Results of the multilevel SEM analysis can be seen in Figure 2 and Table 3. Several important mediation effects were significant at the within-individual level.

Figure 2. Multilevel SEM model representing direct effects between emotion regulation, negative affect dynamics and depressive symptoms

A Within-individual (level 1)

* $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

B Between-individual (level 2)

* $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

Figure 2. (A) At the within-person level, only time-variant variables were used as predictors. Depression factors 'Negative mood and thoughts' and 'Anhedonia' were defined as latent variables which underlie certain items of the depression subscale of the SCL-90-R. All associations were significant and positive between the SCL-90-R items and the underlying factors (see Methods and Table S2 in Supplementary Material for details of multilevel CFA). Both maladaptive emotion regulation strategies showed significant indirect associations with NA intensity, mediated by NA instability and inertia. In addition, NA dynamics showed significant positive indirect relationships with negative mood and thoughts (see Table 3). **(B)** At the between-person level, 'Negative mood and thoughts' and 'Anhedonia' had significant loadings from all the SCL-90-R items (see Table S2 in Supplementary Material). Indirect effects of emotion regulation strategies were significant on NA intensity (mediated by NA dynamics), while no significant indirect effects were found between NA dynamics and depressive symptoms. The direct effects of detrending and control variables (age, gender, stressor exposure) are not shown in these figures (see Table S3 and S4 in Supplementary Materials for detailed results).

Table 3. *Estimated parameters in the multilevel SEM model*

Within-individual (level 1)				
	<i>Estimate s</i>	<i>Std. Est.</i>	<i>Std. Error</i>	<i>p-value</i>
<i>Indirect effects</i>				
Rumination → NA inertia → NA intensity	0.035	0.044	0.012	0.004 **
Exp. suppression → NA inertia → NA intensity	-0.039	-0.056	0.012	0.001 ***
Rumination → NA instability → NA intensity	0.056	0.070	0.022	0.010 **
Exp. suppression → NA instability → NA intensity	0.021	0.029	0.020	0.292
NA inertia → NA intensity → Neg. mood and thoughts	0.159	0.099	0.055	0.004 **
NA instability → NA intensity → Neg. mood and thoughts	0.085	0.194	0.027	0.002 **
NA inertia → NA intensity → Anhedonia	0.151	0.029	0.108	0.160
NA instability → NA intensity → Anhedonia	0.081	0.056	0.056	0.153
<i>Total effects</i>				
Rumination → NA intensity	0.400	0.503	0.037	0.000 ***
Exp. suppression → NA intensity	-0.003	-0.005	0.034	0.922
NA inertia → Neg. mood and thoughts	0.264	0.165	0.114	0.021 *
NA instability → Neg. mood and thoughts	0.063	0.145	0.031	0.044 *
NA inertia → Anhedonia	0.210	0.040	0.332	0.527
NA instability → Anhedonia	0.186	0.130	0.095	0.050 *
Between-individual (level 2)				
	<i>Estimate s</i>	<i>Std. Est.</i>	<i>Std. Error</i>	<i>p-value</i>
<i>Indirect effects</i>				
Rumination → NA inertia → NA intensity	0.345	0.419	0.075	0.000 ***
Exp. suppression → NA inertia → NA intensity	0.089	0.214	0.033	0.007 **
Rumination → NA instability → NA intensity	0.070	0.085	0.036	0.050 *
Exp. suppression → NA instability → NA intensity	-0.024	-0.057	0.014	0.083
NA inertia → NA intensity → Neg. mood and thoughts	1.422	0.346	1.115	0.202
NA instability → NA intensity → Neg. mood and thoughts	0.158	0.092	0.139	0.255
NA inertia → NA intensity → Anhedonia	-0.070	-0.010	2.428	0.977
NA instability → NA intensity → Anhedonia	-0.008	-0.003	0.270	0.977
<i>Total effects</i>				
Rumination → NA intensity	0.505	0.613	0.072	0.000 ***
Exp. suppression → NA intensity	0.063	0.152	0.035	0.068
NA inertia → Neg. mood and thoughts	2.787	0.678	0.620	0.000 ***
NA instability → Neg. mood and thoughts	0.337	0.195	0.194	0.082
NA inertia → Anhedonia	4.587	0.648	0.820	0.000 ***
NA instability → Anhedonia	0.171	0.058	0.401	0.665

* $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

First, rumination's positive total effect on NA intensity was mediated by both NA inertia and instability. That is, if one ruminates more than usual, one is more likely to be in a rigid negative affective state and yet also to have unstable negative affectivity, and both contribute to the well-known association between rumination and elevated negative affect.

Second, expressive suppression showed a significant negative indirect effect via NA inertia on NA intensity. Still, the total effect of expressive suppression on NA intensity was not significant, which is a pattern called 'inconsistent mediation' (MacKinnon et al., 2000). Thus, although suppressing emotions more than usual is associated with less rigid negative affective states, and this is related to reduced negative affect levels, the net effect of expressive suppression is not significant. Perhaps expressive suppression has other correlates which go together with increased negative affect.

Third, both NA inertia and NA instability showed significant positive indirect effects on negative mood and thoughts, mediated by NA intensity. In other words, if one demonstrates either increased rigidity or fluctuation in negative affect as compared to usual, one will also show elevated negative affect, which evidently predicts being in a more depressed state of mind (in terms of mood and thoughts). In case of anhedonia, none of the indirect effects were significant.

Analogous findings emerged at the between-person level. First, the effect of rumination on NA intensity was significantly and positively mediated by both NA inertia and NA instability. This implies that if one ruminates more than others in general, one is more likely to experience less flexible negative affective states and still also to experience more unstable negative affective states, and both contribute to the well-known association between rumination and elevated negative affect.

Second, in contrast to the within-individual level, expressive suppression had a positive indirect effect on NA intensity, which was mediated by NA inertia. In other words, the more

one avoids the expression of negative emotions (i.e., suppressing them) compared to others, the more they have rigid affective functioning and higher levels of negative affect. The total effect of expressive suppression on NA intensity, however, was marginally significant, just as its negative indirect effect on NA intensity via NA instability. At the between-person level, the mediation effects of NA intensity were non-significant between both NA inertia and NA instability and depressive symptoms; however, the total effect of NA inertia on negative mood and thoughts was significant and positive, and NA inertia also had a significant positive effect on anhedonia.

The model was adjusted for time, exposure to stressors, age and gender. Exposure to stressors showed positive associations with both factors of depressive symptoms and NA intensity at the within-individual level, while no significant associations were found at the between-individual level in this regard. Thus, the more stressors are present in someone's life than usual (but not as compared to others), the more likely they are to report stronger depressive symptoms and elevated negative affect. Moreover, significant covariances were found between the two factors of depression, between expressive suppression and rumination as well as between affect dynamics. More detailed results regarding the control and detrending variables as well as included covariances can be found in Table S3 and S4 in the Supplementary Materials.

4. Discussion

The aim of the present study was to explore the within-person associations between affect dynamics (emotional inertia and instability), maladaptive emotion regulation strategies (rumination and expressive suppression) and depressive symptoms during an extremely stressful period of time, when the first wave of the pandemic hit Hungary.

Via multilevel confirmatory factor analysis, we identified two factors of depressive symptoms, anhedonia and negative mood and thoughts. In the multilevel SEM model, we found that rumination and expressive suppression were significant predictors of changes in NA inertia, instability and intensity at the within-individual and also at the between-individual level. Moreover, NA intensity mediated between affect dynamics (NA inertia and instability) and depressive symptoms, but these effects were specific to the within-individual level and to the negative mood and thoughts dimension of depression.

Importantly, rumination and expressive suppression were differently correlated with affect dynamics within vs. between individuals. Rumination was consistently positively associated with the elevation of NA intensity, and this effect was mediated by increases in both NA inertia and NA instability. However, the case of expressive suppression was less clear cut. Within individuals, it showed a negative indirect effect via NA inertia on NA intensity and a non-significant total effect on NA intensity. A non-significant total effect can be the result of direct and indirect effects showing associations with opposite directions (MacKinnon et al., 2000) and one can also establish the presence of a mediation effect when the total effect is not significant (Zhao et al., 2010). On the other hand, expressive suppression was positively related to NA inertia between individuals and did not have a significant total effect on NA intensity.

Regarding the within-individual association of affect dynamics and depression, both NA inertia and instability showed a positive significant indirect relationship with negative mood and thoughts, mediated by NA intensity. This finding is in accordance with the conclusions of previous studies that characterized correlates of depression between individuals (Brose et al., 2015; van de Leemput et al., 2014; Wichers et al., 2016), and for the first time, provides evidence that the association between dynamic indicators and depression can be generalized to the within-individual level. For anhedonia, a tendency-level indirect effect and

significant total effect were observed with NA instability, which were mediated by NA intensity, while no significant effects were found for NA inertia.

However, at the between-individual level, no significant indirect effects were found between affect dynamics and depressive symptoms. Still, one can find significant total effects between affect dynamics and negative mood and thoughts, while NA inertia's total effect on anhedonia also appeared to be significant. Noting that non-significant results do not imply lack of a true effect, we are tempted to speculate about the implications of this result. Our finding of significant within- but non-significant between-person effects leaves the possibility open that previous findings regarding associations between ESM-based indicators and a single trait-like assessment of depression (Brose et al., 2015; Schreuder et al., 2020; Sperry et al., 2020) in fact, may have reflected within-person associations (Hamaker, 2012; Hamaker and Muthén, 2020).

These results are related to the existing literature in various ways. In line with previous findings at the between-person level, rumination was connected to affect dynamics (Koval et al., 2012). Importantly, our results showed that these effects are generalizable to the within-individual level: it seems plausible that greater amounts of unintentional and recurrent negative automatic thoughts contribute to developing less flexible affective functioning. According to previous findings, in case of ruminative thinking, irrelevant negative affective information remains in the working memory as a consequence of impaired functioning of cognitive control (i.e. working memory updating) (Joormann et al., 2011; Koster et al., 2011; Koval et al., 2012). This leads to more intense and inert negative affects, and indirectly, to an elevation in depressive symptoms. These processes seem to occur independently from exposure to stressors.

In terms of emotional instability, it seems plausible that automatic and intrusive negative thoughts also contribute to high fluctuation of negative affective states. As it has been shown before, levels of rumination influence the intensity of negative emotional responses to

negative events (Genet and Siemer, 2012). This suggests that sudden intruding and then easing, but not prolonged automatic negative thoughts (which can also contribute to elevated mean rumination at the within-level) may increase affective instability by inducing more intense emotional responses to stressors that appear from time to time. Furthermore, according to an earlier trait-level investigation (Baer and Sauer, 2011), rumination on anger and irritability showed stronger relationship with affective instability than depression-related rumination. This may imply that rumination that relates to negative affective states with higher levels of arousal (e.g., anger, irritability), is rather connected to emotional instability than inertia. However, to test this assumption, negative affective states with high (e.g., irritability, anger) and low arousal (e.g., sadness, hopelessness) should be investigated separately in terms of their associations with emotion regulation, affect dynamics and depressive symptoms. Also, to discover the precise mechanisms between rumination and NA instability, it is essential to test temporal associations between dynamics of ruminative thinking and dynamics of affect in the future.

The picture is a bit more complicated in the case of expressive suppression: we found significant differences between the within- and the between-person level with regards to how expressive suppression is related to affect dynamics. In line with the literature (Koval et al., 2015b), we found that expressive suppression was positively related to NA inertia across individuals. Still, in our study, within individuals, expressive suppression was negatively connected to NA inertia, which may imply that expressive suppression indicates higher levels of inhibitory control that supports successive downregulation of negative emotions (Rónai et al., in prep.). In line with this, applying expressive suppression is not exclusively detrimental in maintaining mental health (Bonanno et al., 2004); therefore, these results suggest that suppression can only be considered a maladaptive emotion regulation strategy if it turns habitual. To sum up, when people engage in expressive suppression, it is associated with less

inertia, while in general, people who tend to show more inertia also tend to suppress their emotions more.

Exposure to stressors showed significant positive relationships with depressive symptoms and NA intensity in our study. This is in agreement with the well-established finding that stress is an important risk factor of depressive symptoms (Beck and Bredemeier, 2016) and also implicates that the increase in stressors may have decisively contributed to the strengthening of depressive symptoms in the general population during the first wave of the pandemic (see Ettman et al., 2020). Yet, mediation effects between maladaptive emotion regulation strategies, affect dynamics and NA intensity were significant after detrending the data and adjusting for exposure to stressors. This not only demonstrates the robustness of our findings but it also implies that emotional inertia and instability are not just consequences of exposure to stressors (Koval et al., 2015a, 2013), but they may indeed stem from the application of maladaptive emotion regulation strategies (Koval et al., 2012; Thompson et al., 2012; Trull et al., 2015).

Our study also informs the debate about the incremental validity of affective dynamics. We revealed complex mediation effects between maladaptive emotion regulation strategies, affect dynamics, negative affective intensity and depressive symptoms. NA intensity was a mediator between affect dynamics and depressive symptoms, that is, NA inertia and instability were both (indirectly) linked to depressive symptoms, which is in line with several earlier results (Brose et al., 2015; Houben et al., 2015; Sperry et al., 2020; Thompson et al., 2012; Trull et al., 2015; van de Leemput et al., 2014). However, recent studies have claimed that emotional inertia and instability have limited incremental predictive value above NA intensity in explaining variance in depression (Dejonckheere et al., 2019; Houben and Kuppens, 2020). According to these studies, affect dynamics' poor unique predictive value can be attributed to significant redundancies between inertia, instability and intensity of affect (Dejonckheere et

al., 2019; Houben and Kuppens, 2020; Wendt et al., 2020). However, it should be noted that NA intensity indicated the mean levels of negative affect within three-day-blocks, while one of the key outcome variables - a depressive symptom dimension - also comprised generally elevated negative mood in the same time period (e.g., feeling sad or lonely in previous three days). In this regard, there is a large conceptual overlap between NA intensity and depression, since one can argue that NA intensity is, at least in terms of content, a psychological construct that is very similar to a core symptom of depression, elevated negative mood. In this aspect, it does not seem surprising that NA intensity has a stronger explanatory power in predicting depressive symptoms of negative mood and thoughts, as compared to affect dynamics that capture very specific temporal information. Thus, we suggest that NA intensity, as the mean level of negative affect, in a well-defined time-window, should be considered an ESM-based proxy for depression and the important question is how emotion regulation strategies are connected to this proxy and affect dynamics.

Based on our mediation model, one may speculate about the dynamic relationships between maladaptive emotion regulation, affect dynamics, NA intensity, and depressive symptoms. Elevated tone and intensity of NA (i.e., mean levels) may be the consequence of a breakdown in emotion regulation, that is reflected in a specific pattern of affect dynamics (Koval et al., 2012; Thompson et al., 2012). Then, the elevation in NA dynamics and intensity can form a bridge between maladaptive emotion regulation and mood- and cognition-related symptoms of depression.

A significant strength of this study is that we evaluated the effects of affect dynamics together, within the same models that simultaneously considered associations within and between individuals (Fisher et al., 2018). The models were fitted on a rich time-series dataset that included data not only on affective states but also depression with a high temporal resolution, which is a significant contribution to previous studies that assessed depression

before and/or after the longitudinal examination (Brose et al., 2015; Schreuder et al., 2020; Sperry et al., 2020). Also, we pointed out that distinct aspects of depression might be differently associated with affect dynamics, which contrasts with previous studies that treated depression as a homogeneous construct (see Houben and Kuppens, 2020; Koval et al., 2013, 2012; Schreuder et al., 2020). A limitation of the study is that affective states were assessed by self-report questionnaires; further studies should consider psychophysiological measures that may provide a more detailed and precise picture of temporal affective functioning. In addition, our sample mainly included female and highly educated participants, which limits the generalizability of these results to the general population.

To conclude, our study is the first that examined within-person associations between temporal changes in maladaptive emotion regulation, dynamics of affective states, and different aspects of depression on a narrow, few-day basis. Also, our findings are informative about the utility of momentary affective states in predicting depressive symptoms during heightened stress exposure and times of crisis. Furthermore, our study may have clinical implications: it seems that we can get closer to personalized prediction of exacerbation of depressive symptoms through temporal changes in stress- and affect-related phenomena that can be well captured with simple self-reported measurements and digital tools.

Ethical standards

Participation was voluntary and participants provided informed consent. The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008. The study was approved by the United Ethical Review Committee for Research in Psychology, Hungary (reference number: 2020-40). Extended information on ethical considerations of the study can be found in Supplementary Materials.

Acknowledgement

We would like to thank all participants for their time and availability and Kinga Farkas MD PhD for her support. We are grateful to Ágnes Szöllősi PhD and Dániel Petrovszki for their comments on an earlier version of the manuscript.

Financial support

Bertalan Polner was supported by BME Biotechnology Project (FIKP-BIO) and NKFI/OTKA K 12859. The sponsor was not involved in study design; in the collection, analysis and interpretation of data; in the writing of the report; and in the decision to submit the article for publication

Conflict of Interest

None.

References

- Alessandri, G., De Longis, E., Eisenberg, N., Hobfoll, S.E., 2020. A multilevel moderated mediational model of the daily relationships between hassles, exhaustion, ego-resiliency and resulting emotional inertia. *J. Res. Personal.* 85, 103913. <https://doi.org/10.1016/j.jrp.2020.103913>
- Arslan, R.C., Walther, M.P., Tata, C.S., 2020. formr: A study framework allowing for automated feedback generation and complex longitudinal experience-sampling studies using R. *Behav. Res. Methods* 52, 376–387. <https://doi.org/10.3758/s13428-019-01236-y>
- Baer, R.A., Sauer, S.E., 2011. Relationships between depressive rumination, anger rumination, and borderline personality features. *Personal. Disord.* 2, 142–150. <https://doi.org/10.1037/a0019478>
- Bates, D., Mächler, M., Bolker, B., Walker, S., 2015. Fitting Linear Mixed-Effects Models Using lme4. *J. Stat. Softw.* 67, 1–48. <https://doi.org/10.18637/jss.v067.i01>
- Beck, A.T., Bredemeier, K., 2016. A Unified Model of Depression: Integrating Clinical, Cognitive, Biological, and Evolutionary Perspectives. *Clin. Psychol. Sci.* 4, 596–619. <https://doi.org/10.1177/2167702616628523>
- Bonanno, G.A., Papa, A., Lalande, K., Westphal, M., Coifman, K., 2004. The Importance of Being Flexible: The Ability to Both Enhance and Suppress Emotional Expression Predicts Long-Term Adjustment. *Psychol. Sci.* 15, 482–487. <https://doi.org/10.1111/j.0956-7976.2004.00705.x>
- Brans, K., Koval, P., Verduyn, P., Lim, Y.L., Kuppens, P., 2013. The regulation of negative and positive affect in daily life. *Emotion* 13, 926–939. <https://doi.org/10.1037/a0032400>
- Bringmann, L.F., Pe, M.L., Vissers, N., Ceulemans, E., Borsboom, D., Vanpaemel, W.,

- Tuerlinckx, F., Kuppens, P., 2016. Assessing Temporal Emotion Dynamics Using Networks. *Assessment* 23, 425–435. <https://doi.org/10.1177/1073191116645909>
- Brockman, R., Ciarrochi, J., Parker, P., Kashdan, T., 2017. Emotion regulation strategies in daily life: mindfulness, cognitive reappraisal and emotion suppression. *Cogn. Behav. Ther.* 46, 91–113. <https://doi.org/10.1080/16506073.2016.1218926>
- Brose, A., Schmiedek, F., Koval, P., Kuppens, P., 2015. Emotional inertia contributes to depressive symptoms beyond perseverative thinking. *Cogn. Emot.* 29, 527–538. <https://doi.org/10.1080/02699931.2014.916252>
- Colombo, D., Fernández-Álvarez, J., Suso-Ribera, C., Cipresso, P., Valev, H., Leufkens, T., Sas, C., Garcia-Palacios, A., Riva, G., Botella, C., 2020. The need for change: Understanding emotion regulation antecedents and consequences using ecological momentary assessment. *Emot. Wash. DC* 20, 30–36. <https://doi.org/10.1037/emo0000671>
- Csikszentmihalyi, M., Larson, R., 2014. Validity and Reliability of the Experience-Sampling Method, in: Csikszentmihalyi, M. (Ed.), *Flow and the Foundations of Positive Psychology: The Collected Works of Mihaly Csikszentmihalyi*. Springer Netherlands, Dordrecht, pp. 35–54. https://doi.org/10.1007/978-94-017-9088-8_3
- Dalgleish, T., Yiend, J., Schweizer, S., Dunn, B.D., 2009. Ironic effects of emotion suppression when recounting distressing memories. *Emot. Wash. DC* 9, 744–749. <https://doi.org/10.1037/a0017290>
- Dejonckheere, E., Mestdagh, M., Houben, M., Rutten, I., Sels, L., Kuppens, P., Tuerlinckx, F., 2019. Complex affect dynamics add limited information to the prediction of psychological well-being. *Nat. Hum. Behav.* 3, 478–491. <https://doi.org/10.1038/s41562-019-0555-0>
- Derogatis, L.R., Spitz, K.L., 1999. The SCL-90-R, Brief Symptom Inventory, and Matching

- Clinical Rating Scales, in: *The Use of Psychological Testing for Treatment Planning and Outcomes Assessment*, 2nd Ed. Lawrence Erlbaum Associates Publishers, Mahwah, NJ, US, pp. 679–724.
- Ettman, C.K., Abdalla, S.M., Cohen, G.H., Sampson, L., Vivier, P.M., Galea, S., 2020. Prevalence of Depression Symptoms in US Adults Before and During the COVID-19 Pandemic. *JAMA Netw. Open* 3, e2019686.
<https://doi.org/10.1001/jamanetworkopen.2020.19686>
- Fisher, A.J., Medaglia, J.D., Jeronimus, B.F., 2018. Lack of group-to-individual generalizability is a threat to human subjects research. *Proc. Natl. Acad. Sci.* 115, E6106–E6115. <https://doi.org/10.1073/pnas.1711978115>
- Genet, J.J., Siemer, M., 2012. Rumination moderates the effects of daily events on negative mood: results from a diary study. *Emot. Wash. DC* 12, 1329–1339.
<https://doi.org/10.1037/a0028070>
- Gillan, C.M., Rutledge, R.B., 2021. Smartphones and the Neuroscience of Mental Health. *Annu. Rev. Neurosci.* 44, 129–151. <https://doi.org/10.1146/annurev-neuro-101220-014053>
- Gross, J.J., 2015. Emotion Regulation: Current Status and Future Prospects. *Psychol. Inq.* 26, 1–26. <https://doi.org/10.1080/1047840X.2014.940781>
- Hamaker, E.L., 2012. Why researchers should think “within-person”: A paradigmatic rationale, in: *Handbook of Research Methods for Studying Daily Life*. The Guilford Press, New York, NY, US, pp. 43–61.
- Hamaker, E.L., Muthén, B., 2020. The fixed versus random effects debate and how it relates to centering in multilevel modeling. *Psychol. Methods* 25, 365–379.
<https://doi.org/10.1037/met0000239>
- Hitchcock, P.F., Fried, E.I., Frank, M.J., 2022. Computational Psychiatry Needs Time and

- Context. *Annu. Rev. Psychol.* 73, 243–270. <https://doi.org/10.1146/annurev-psych-021621-124910>
- Houben, M., Kuppens, P., 2020. Emotion Dynamics and the Association With Depressive Features and Borderline Personality Disorder Traits: Unique, Specific, and Prospective Relationships. *Clin. Psychol. Sci.* 8, 226–239. <https://doi.org/10.1177/2167702619871962>
- Houben, M., Van Den Noortgate, W., Kuppens, P., 2015. The relation between short-term emotion dynamics and psychological well-being: A meta-analysis. *Psychol. Bull.* 141, 901–930. <https://doi.org/10.1037/a0038822>
- Jahng, S., Wood, P.K., Trull, T.J., 2008. Analysis of affective instability in ecological momentary assessment: Indices using successive difference and group comparison via multilevel modeling. *Psychol. Methods* 13, 354–375. <https://doi.org/10.1037/a0014173>
- Joormann, J., Levens, S.M., Gotlib, I.H., 2011. Sticky thoughts: depression and rumination are associated with difficulties manipulating emotional material in working memory. *Psychol. Sci.* 22, 979–983. <https://doi.org/10.1177/0956797611415539>
- Kennedy, S.H., 2008. Core symptoms of major depressive disorder: relevance to diagnosis and treatment. *Dialogues Clin. Neurosci.* 10, 271–277.
- Köllő, J., 2020. Employment during the first wave of COVID-19, in: *The Hungarian Labour Market 2020*. Institute of Economics, Centre for Economic and Regional Studies., Budapest.
- Koster, E.H.W., De Lissnyder, E., Derakshan, N., De Raedt, R., 2011. Understanding depressive rumination from a cognitive science perspective: The impaired disengagement hypothesis. *Clin. Psychol. Rev.* 31, 138–145. <https://doi.org/10.1016/j.cpr.2010.08.005>

- Koval, P., Brose, A., Pe, M.L., Houben, M., Erbas, Y., Champagne, D., Kuppens, P., 2015a. Emotional inertia and external events: The roles of exposure, reactivity, and recovery. *Emot. Wash. DC* 15, 625–636. <https://doi.org/10.1037/emo0000059>
- Koval, P., Butler, E.A., Hollenstein, T., Lanteigne, D., Kuppens, P., 2015b. Emotion regulation and the temporal dynamics of emotions: Effects of cognitive reappraisal and expressive suppression on emotional inertia. *Cogn. Emot.* 29, 831–851. <https://doi.org/10.1080/02699931.2014.948388>
- Koval, P., Kuppens, P., Allen, N.B., Sheeber, L., 2012. Getting stuck in depression: The roles of rumination and emotional inertia. *Cogn. Emot.* 26, 1412–1427. <https://doi.org/10.1080/02699931.2012.667392>
- Koval, P., Pe, M.L., Meers, K., Kuppens, P., 2013. Affect dynamics in relation to depressive symptoms: Variable, unstable or inert? *Emotion* 13, 1132–1141. <https://doi.org/10.1037/a0033579>
- Kuppens, P., Allen, N.B., Sheeber, L., 2010. Emotional inertia and psychological maladjustment. *Psychol. Sci.* 21, 984–991. <https://doi.org/10.1177/0956797610372634>
- Kuppens, P., Sheeber, L.B., Yap, M.B.H., Whittle, S., Simmons, J.G., Allen, N.B., 2012. Emotional inertia prospectively predicts the onset of depressive disorder in adolescence. *Emotion* 12, 283–289. <https://doi.org/10.1037/a0025046>
- Kuppens, P., Verduyn, P., 2017. Emotion dynamics. *Curr. Opin. Psychol.* 17, 22–26. <https://doi.org/10.1016/j.copsyc.2017.06.004>
- MacKinnon, D.P., Krull, J.L., Lockwood, C.M., 2000. Equivalence of the Mediation, Confounding and Suppression Effect. *Prev. Sci. Off. J. Soc. Prev. Res.* 1, 173.
- Martín-Brufau, R., Suso-Ribera, C., Corbalán, J., 2020. Emotion Network Analysis During COVID-19 Quarantine - A Longitudinal Study. *Front. Psychol.* 11, 2802.

- <https://doi.org/10.3389/fpsyg.2020.559572>
- McRae, K., Gross, J.J., 2020. Emotion regulation. *Emot. Wash. DC* 20, 1–9.
- <https://doi.org/10.1037/emo0000703>
- Myin-Germeys, I., Kasanova, Z., Vaessen, T., Vachon, H., Kirtley, O., Viechtbauer, W., Reininghaus, U., 2018. Experience sampling methodology in mental health research: new insights and technical developments. *World Psychiatry* 17, 123–132.
- <https://doi.org/10.1002/wps.20513>
- Myin-Germeys, I., Oorschot, M., Collip, D., Lataster, J., Delespaul, P., van Os, J., 2009. Experience sampling research in psychopathology: opening the black box of daily life. *Psychol. Med.* 39, 1533–1547. <https://doi.org/10.1017/S0033291708004947>
- Nolen-Hoeksema, S., Wisco, B.E., Lyubomirsky, S., 2008. Rethinking Rumination. *Perspect. Psychol. Sci. J. Assoc. Psychol. Sci.* 3, 400–424. <https://doi.org/10.1111/j.1745-6924.2008.00088.x>
- R Core Team (2020). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. <https://www.R-project.org/>.
- Rosseel, Y., 2012. lavaan: An R Package for Structural Equation Modeling. *J. Stat. Softw.* 48, 1–36. <https://doi.org/10.18637/jss.v048.i02>
- RStudio Team (2020). RStudio: Integrated Development for R. RStudio, PBC, Boston, MA <http://www.rstudio.com/>.
- Russell, J.A., 2003. Core affect and the psychological construction of emotion. *Psychol. Rev.* 110, 145–172. <https://doi.org/10.1037/0033-295X.110.1.145>
- Schreuder, M.J., Hartman, C.A., George, S.V., Menne-Lothmann, C., Decoster, J., van Winkel, R., Delespaul, P., De Hert, M., Derom, C., Thiery, E., Rutten, B.P.F., Jacobs, N., van Os, J., Wigman, J.T.W., Wichers, M., 2020. Early warning signals in psychopathology: what do they tell? *BMC Med.* 18, 269.

<https://doi.org/10.1186/s12916-020-01742-3>

Simor, P., Polner, B., Báthori, N., Sifuentes-Ortega, R., Van Roy, A., Albajara Sáenz, A., Luque González, A., Benkirane, O., Nagy, T., Peigneux, P., 2021. Home confinement during the COVID-19: day-to-day associations of sleep quality with rumination, psychotic-like experiences, and somatic symptoms. *Sleep* 44, zsab029.

<https://doi.org/10.1093/sleep/zsab029>

Sperry, S.H., Kwapil, T., 2020. Comparing Static and Dynamic Measures of Affect Intensity and Affective Lability: Do they Measure the Same Thing?

<https://doi.org/10.31234/osf.io/zj325>

Sperry, S.H., Walsh, M.A., Kwapil, T.R., 2020. Emotion dynamics concurrently and prospectively predict mood psychopathology. *J. Affect. Disord.* 261, 67–75.

<https://doi.org/10.1016/j.jad.2019.09.076>

Thompson, R.J., Mata, J., Jaeggi, S.M., Buschkuhl, M., Jonides, J., Gotlib, I.H., 2012. The Everyday Emotional Experience of Adults with Major Depressive Disorder: Examining Emotional Instability, Inertia, and Reactivity. *J. Abnorm. Psychol.* 121, 819–829. <https://doi.org/10.1037/a0027978>

Trull, T.J., Lane, S.P., Koval, P., Ebner-Priemer, U.W., 2015. Affective Dynamics in Psychopathology. *Emot. Rev. J. Int. Soc. Res. Emot.* 7, 355–361.

<https://doi.org/10.1177/1754073915590617>

van de Leemput, I.A., Wichers, M., Cramer, A.O.J., Borsboom, D., Tuerlinckx, F., Kuppens, P., van Nes, E.H., Viechtbauer, W., Giltay, E.J., Aggen, S.H., Derom, C., Jacobs, N., Kendler, K.S., van der Maas, H.L.J., Neale, M.C., Peeters, F., Thiery, E., Zachar, P., Scheffer, M., 2014. Critical slowing down as early warning for the onset and termination of depression. *Proc. Natl. Acad. Sci. U. S. A.* 111, 87–92.

<https://doi.org/10.1073/pnas.1312114110>

- Wegner, D.M., 1994. Ironic processes of mental control. *Psychol. Rev.* 101, 34–52.
<https://doi.org/10.1037/0033-295X.101.1.34>
- Wendt, L.P., Wright, A.G.C., Pilkonis, P.A., Woods, W.C., Denissen, J.J.A., Kühnel, A., Zimmermann, J., 2020. Indicators of Affect Dynamics: Structure, Reliability, and Personality Correlates. *Eur. J. Personal.* 34, 1060–1072.
<https://doi.org/10.1002/per.2277>
- Wichers, M., Groot, P.C., Psychosystems, ESM Group, EWS Group, 2016. Critical Slowing Down as a Personalized Early Warning Signal for Depression. *Psychother. Psychosom.* 85, 114–116. <https://doi.org/10.1159/000441458>
- Wichers, M., Smit, A.C., Snippe, E., 2020. Early Warning Signals Based on Momentary Affect Dynamics can Expose Nearby Transitions in Depression: A Confirmatory Single-Subject Time-Series Study. *J. Pers.-Oriented Res.* 6, 1–15.
<https://doi.org/10.17505/jpor.2020.22042>
- Zhao, X., Lynch, J.G., Jr., Chen, Q., 2010. Reconsidering Baron and Kenny: Myths and Truths about Mediation Analysis. *J. Consum. Res.* 37, 197–206.
<https://doi.org/10.1086/651257>

Getting the blues: negative affect dynamics mediate the within-person association of maladaptive emotion regulation and depression

Supplementary Material

Levente Rónai^{a1}, Bertalan Polner^a

^aDepartment of Cognitive Science, Budapest University of Technology and Economics, Egry József street 1., 1111 Budapest, Hungary

¹Corresponding author: Levente Rónai, Budapest 1111, Egry József street 1., T building, V. floor 506, telephone + 36 1 463 1273, fax: +36 1 463-1072
e-mail: ronai.levente@ttk.bme.hu

Additional information on ethical considerations

Participation in the study was voluntary, in return for which, if requested, we sent feedback figures to participants about their daily changes in emotional states. Study participation could be terminated at any time without justification. Data collection happened through a web application called formr.org, which collected responses during the study using links sent to participants' email addresses. Participants' email addresses were used solely for collecting responses and for contact and communication with the participants. Email addresses were deleted in all cases prior to data cleaning and processing to anonymize participants. Data of participants were only available to researchers on formr.org. For more information on formr.org security settings:

<https://link.springer.com/article/10.3758/s13428-019-01236-y>

Furthermore, during the period of COVID-19, participants could go under extraordinary high mental stress, which may have been associated with increased anxiety and frustration. Therefore, we made links available to websites that provided information on maintaining mental health for both adults and children during the COVID-19 pandemic. In addition, we have published contact information through which participants can reach qualified professionals who provide free psychological help and support to the participant during the pandemic. In addition, we published the contact email address of the study on all formr.org platforms available to participants, through which they could contact us at any time regarding questions or problems related to the study.

Principal component loadings (Table S1).

Table S1. Principal component loadings of NA and PA*

<i>Items</i>	<i>Negative Affect (NA)</i>	<i>Positive Affect (PA)*</i>
Sad	0.50	-0.38
Calm	-0.61	0.28
Afraid	0.54	-0.15
Distracted	0.85	-0.03
Enthusiastic	-0.02	0.91
Cheerful	-0.12	0.85
Irritated	0.85	0.10
Active	0.11	0.93
Angry	0.84	0.10

*Dynamics of PA were not analyzed in this study

Multilevel Confirmatory Factor Analysis (Table S2).

Table S2. Factor loadings and covariances of the two depression factors based on multilevel CFA

<i>Negative mood and thoughts</i>			<i>Anhedonia</i>		
<i>Item # (keyword)</i>	<i>Between- person factor loading</i>	<i>Within-person factor loading</i>	<i>Item # (keyword)</i>	<i>Between- person factor loading</i>	<i>Within-person factor loading</i>
# 1 (sexual)	0.555	0.238	# 2 (dimin. energy)	0.914	0.620
# 3 (death)	0.650	0.315	# 10 (effort)	0.964	0.786
# 4 (crying)	0.772	0.412	# 12 (lack of interest)	0.922	0.606
# 5 (trapped)	0.805	0.542	<i>Covariances between Anhedonia and Negative mood and thoughts</i>		
# 6 (self-blame)	0.799	0.461	<i>Between-person</i>	<i>Within-person</i>	
# 7 (loneliness)	0.753	0.547	<i>Est. = 0.81, p < 0.001</i>	<i>Est. = 0.67, p < 0.001</i>	
# 8 (sad)	0.911	0.623			
# 9 (worrying)	0.747	0.470			
# 11 (hopelessness)	0.908	0.607			
# 13 (worthlessness)	0.954	0.580			

Structure and items of the stressor-exposure questionnaire.

Please indicate if any of the following events and situations have occurred to you in the last three days. Answering is optional.

Stressors:

1. I lost my job.
2. My income dropped.
3. Due to changes in circumstances, I had to rethink my plans for my studies.
4. The health of (a) significant other(s) deteriorated significantly.
5. My health deteriorated significantly.
6. I had a conflict with significant others outside the workplace (e.g., with friends, family)
7. I had a conflict at work (e.g., with a co-worker, boss).
8. I could not pay for essential things (e.g., food, bills, medications).
9. My housing situation has changed (e.g., moving to another place, new people have moved into a household with me, loss of residence).
10. Due to the increased workload, working or studying interfered with relaxing.
11. For reasons beyond my control, I did not have the opportunity to spend time with significant others (e.g., friends, family) with whom I do not live together.
12. Other significant negative event, change

Support:

1. I got a new job.
2. I received financial support above usual (e.g., from family, friends, or the state).
3. My income increased.
4. I spent time with significant others (e.g., family, friends) with whom I do not live together.
5. My health improved significantly.
6. The health of (a) significant other(s) improved significantly.
7. I made progress in my work (e.g., completing an important project, task).
8. I made progress in my studies (e.g., successful exam).
9. Other significant positive event, change

Within-level results of the multilevel SEM model (Table S3).

Level 1 (within-person)									
Latent variable: Negative mood and thoughts					Latent variable: Anhedonia				
<i>SCL-90-R item</i>	<i>Estimate</i>	<i>SE</i>	<i>z</i>	<i>p</i>	<i>SCL-90-R item</i>	<i>Estimate</i>	<i>SE</i>	<i>z</i>	<i>p</i>
# 1	1.000 *	* Fixed parameter			# 2	1.000	* Fixed parameter		
# 3	1.188	0.372	3.195	1.213	# 12	1.210	0.138	8.815	0.000
# 4	2.035	0.578	3.518	1.056	# 10	1.056	0.127	8.281	0.000
# 5	2.755	0.744	3.705	0.000	Direct effects				
# 6	2.087	0.582	3.588	0.000	Outcome: Anhedonia				
# 7	2.537	0.676	3.751	0.000	<i>Predictors</i>	<i>Estimate</i>	<i>SE</i>	<i>z</i>	<i>p</i>
# 8	3.233	0.860	3.759	0.000	NA intensity	0.059	0.353	0.167	0.867
# 9	2.222	0.609	3.650	0.000	NA instability	0.105	0.113	0.932	0.351
# 11	2.713	0.715	3.795	0.000	NA intensity	0.156	0.108	1.441	0.150
# 13	2.926	0.775	3.776	0.000	Stressor expo.	0.131	0.039	3.327	0.001
Direct effects					Number of stressor survey	-0.016	0.013	-1.180	0.238
Outcome: Negative mood and thoughts					Direct effects				
<i>Predictors</i>	<i>Estimate</i>	<i>SE</i>	<i>z</i>	<i>p</i>	Outcome: NA intensity				
NA intensity	0.105	0.102	1.027	0.305	<i>Predictors</i>	<i>Estimate</i>	<i>SE</i>	<i>z</i>	<i>p</i>
NA instability	-0.022	0.032	-0.668	0.504	Rumination	0.309	0.032	9.731	0.000
NA intensity	0.164	0.051	3.234	0.001	Exp. suppression	0.016	0.028	0.549	0.583
Stressor expo.	0.042	0.015	2.801	0.005	NA intensity	0.968	0.154	6.296	0.000
Number of stressor survey	-0.004	0.004	-1.120	0.263	NA instability	0.516	0.043	12.113	0.000
Direct effects					Stressor expo.	0.027	0.017	1.632	0.103
Outcome: NA inertia					Number of stressor survey	0.008	0.006	1.425	0.154
<i>Predictors</i>	<i>Estimate</i>	<i>SE</i>	<i>z</i>	<i>p</i>	Direct effects				
Rumination	0.036	0.011	3.208	0.001	Outcome: NA instability				
Exp. suppression	-0.041	0.010	-4.026	0.000	<i>Predictors</i>	<i>Estimate</i>	<i>SE</i>	<i>z</i>	<i>p</i>
Stressor expo.	-0.003	0.006	-0.534	0.593	Rumination	0.109	0.042	2.614	0.009
Number of stressor survey	0.002	0.002	1.152	0.249	Exp. suppression	0.040	0.038	1.057	0.291
Covariances					Stressor expo.	0.024	0.023	1.055	0.291
<i>Variables</i>	<i>Estimate</i>	<i>SE</i>	<i>z</i>	<i>p</i>	Number of stressor survey	-0.029	0.007	-3.912	0.000
NA inertia ~ NA instability	-0.010	0.002	-5.037	0.000					
Negative mood and thoughts ~ Anhedonia	0.049	0.014	3.446	0.001					

Between-level results of the multilevel SEM model (Table S4).

Level 2 (between-person)									
Latent variable: Negative mood and thoughts					Latent variable: Anhedonia				
<i>SCL-90-R item</i>	<i>Estimate</i>	<i>SE</i>	<i>z</i>	<i>p</i>	<i>SCL-90-R item</i>	<i>Estimate</i>	<i>SE</i>	<i>z</i>	<i>p</i>
# 1	1.000	* Fixed parameter			# 2	1.000	* Fixed parameter		
# 3	1.096	0.225	4.870	1.140	# 12	1.141	0.087	13.164	0.000
# 4	1.508	0.287	5.254	0.981	# 10	0.981	0.089	10.978	0.000
# 5	1.469	0.272	5.406	0.000	Direct effects				
# 6	1.671	0.311	5.365	0.000	Outcome: Anhedonia				
# 7	1.661	0.313	5.306	0.000	<i>Predictors</i>	<i>Estimate</i>	<i>SE</i>	<i>z</i>	<i>p</i>
# 8	1.766	0.309	5.723	0.000	NA inertia	4.657	2.882	1.616	0.106
# 9	1.757	0.325	5.404	0.000	NA instability	0.182	0.475	0.382	0.702
# 11	1.909	0.329	5.805	0.000	NA intensity	-0.021	0.715	-0.029	0.977
# 13	1.894	0.322	5.884	0.000	Stressor exp.	0.219	0.148	1.480	0.139
Direct effects					Age	0.004	0.006	0.670	0.503
Outcome: Negative mood and thoughts					Male	-0.183	0.260	-0.702	0.483
<i>Predictors</i>	<i>Estimate</i>	<i>SE</i>	<i>z</i>	<i>p</i>	Other	1.900	0.766	2.482	0.013
NA inertia	1.365	1.376	0.992	0.321	Direct effects				
NA instability	0.179	0.211	0.847	0.397	Outcome: NA intensity				
NA intensity	0.419	0.342	1.224	0.221	<i>Predictors</i>	<i>Estimate</i>	<i>SE</i>	<i>z</i>	<i>p</i>
Stressor expo.	0.055	0.066	0.829	0.407	Rumination	0.090	0.066	1.352	0.176
Age	0.002	0.003	0.900	0.368	Exp. suppression	-0.002	0.029	-0.067	0.946
Male	-0.101	0.115	-0.873	0.383	NA inertia	3.393	0.383	8.863	0.000
Other	-0.124	0.350	-0.355	0.723	NA instability	0.378	0.156	2.427	0.015
Direct effects					Stressor expo.	-0.057	0.047	-1.202	0.229
Outcome: NA inertia					Age	-0.001	0.002	-0.301	0.763
<i>Predictors</i>	<i>Estimate</i>	<i>SE</i>	<i>z</i>	<i>p</i>	Male	-0.043	0.092	-0.464	0.643
Rumination	0.102	0.019	5.468	0.000	Other	-0.113	0.242	-0.468	0.640
Exp. suppression	0.026	0.009	2.934	0.003	Direct effects				
Stressor expo.	0.014	0.017	0.865	0.387	Outcome: NA instability				
Age	-0.002	0.001	-2.195	0.028	<i>Predictors</i>	<i>Estimate</i>	<i>SE</i>	<i>z</i>	<i>p</i>
Male	0.012	0.030	0.408	0.683	Rumination	0.184	0.056	3.324	0.001
Other	0.069	0.099	0.699	0.485	Exp. suppression	-0.063	0.026	-2.401	0.016
Covariances					Stressor expo.	0.128	0.051	2.503	0.012
<i>Variables</i>	<i>Estimate</i>	<i>SE</i>	<i>z</i>	<i>p</i>	Age	-0.002	0.002	-0.817	0.414
NA inertia ~ NA instability	0.002	0.003	0.785	0.433	Male	-0.281	0.088	-3.178	0.001
Negative mood and thoughts ~ Anhedonia	0.121	0.036	3.405	0.001	Other	-0.254	0.279	-0.912	0.362