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Do daily mood fluctuations activate ruminative thoughts as a mental habit? Results from an ecological momentary assessment study☆

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ABSTRACT

It has been suggested that mental habits may underpin a heightened disposition to engage in rumination in response to negative mood. The aim of the current study was to assess the role of habit in the dynamic interplay between affect and ruminative thinking in the flow of daily life experiences. Using mobile ecological momentary assessment, 97 participants recorded affect and rumination ten times daily over six days, after completing measures of trait ruminative brooding and habitual characteristics of negative thinking (e.g. automaticity, lack of conscious awareness, intent and control). Momentary fluctuations in negative (increased) and positive (decreased) affect was prospectively associated with greater rumination-levels at the next sampling occasion. The degree to which affect triggered a subsequent ruminative response was moderated by habitual characteristics of negative thinking in a theoretically consistent way. Stronger temporal pairing of negative affect and rumination was also associated with greater emotional inertia but less carry-over of rumination from one moment to the next. Depression vulnerability may be in the form of rumination being habitually triggered in response to momentary fluctuations in affect, with deleterious effect on mood. The findings may have clinical implications, as targeting the habitual nature of rumination might help reduce depression vulnerability.

1. Introduction

Ruminative thinking is critical in the onset and maintenance of major depressive disorder (Wisco & Nolen-Hoeksema, 2008) and has been identified as a transdiagnostic vulnerability factor for a number of aversive outcomes (e.g. anxiety, eating disorder, alcohol misuse; Aldao, Nolen-Hoeksema, & Scweizer, 2010). Rumination is a negative thinking style that involves repetitively and passively dwelling on the causes, meanings, and consequences of one's feelings and distress (Nolen--Hoeksema, 1991). Considerable evidence suggests that rumination exacerbates negative affect and cognition, impairs problem solving, and leads to more persistent periods of dysphoric mood (Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008).

The Response Styles Theory defines rumination as an enduring, stable, and *habitual-like tendency* (Nolen-Hoeksema et al., 2008) suggesting that mental habits may underpin a heightened disposition to engage in rumination. This is in line with descriptions of rumination as a habit in the depression literature (see e.g. Hertel, 2004; Watkins & Baracaia, 2001) and recent theoretical conceptualizations of depression vulnerability (e.g. Farb, Irving, Aderson, & Segal, 2015; Koster, De Lissnyder, Derakshan, & De Raedt, 2011; Shaw, Hilt, & Starr, 2019). Habits are formed by learned associations between behavioural responses and their performance contexts. Once formed, context cues become automatic triggers for the behaviour, such that it is controlled solely by the presence of the context cue, rather than individual's goals or motivations (Triandis, 1977; Wood & Neal, 2007). Habits are characterized by a lack of awareness and conscious intent, are mentally efficient, and can be difficult to control (Verplanken, Friborg, Want, Trafimow, & Wolf, 2007).

Watkins and Nolen-Hoeksema (2014) proposed a habit-goal

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framework wherein rumination is seen as a mental habit that is initiated without conscious awareness or intent in response to negative mood. Transient periods of rumination are thought to arise when people try to cope with discrepancies between desired states and their present reality. This process is considered adaptive when ruminating about the discrepancy helps reach important goals, however, when goals are repeatedly not reached, rumination persists and mood deteriorates (Martin & Tesser, 1996; Watkins, 2008). When people consistently rely on passive, negative and abstract ruminative thoughts to cope with such discrepancies, negative affect and ruminative thinking are paired over time, turning rumination into a habit that is triggered by context (i.e., negative affect) rather than goals or intentions. Maladaptive rumination is therefore expected to be associated with heightened habitual characteristics (i.e., be more repetitive and automatic) compared to other less maladaptive forms of rumination.

Nonetheless, the notion of rumination as a mental habit has rarely been directly tested. Verplanken et al. (2007) used the Habit Index of Negative Thinking (HINT) - a self-report measure of habitual characteristics of negative thoughts (i.e., repetition, lack of conscious awareness and deliberate intent, mental efficiency, lack of control and self-descriptiveness) - and found that ruminative thoughts were strongly correlated with heightened habitual characteristics. Consistent with this, Ólafsson, Guðmundsdóttir, Björnsdóttir, and Snorrason (2020) found that ruminative brooding, a maladaptive form of rumination, was associated with heightened habitual characteristics whereas ruminative pondering, a more adaptive form of rumination, was not. Although promising, these findings are limited in a number of ways. Because rumination is measured at a single time point and averaged across time, they may not generalize to momentary fluctuations in rumination and affect. Participants also report on their rumination by thinking back to a time when they felt sad and recall their experiences, increasing the probability of retrospective bias. In a similar vein, previous findings do not allow for an inference about the temporal relationship between affect and rumination, rendering causal inference impossible.

One way to address these shortcomings is to use more ecologically valid assessment procedures, such as Ecological Momentary Assessment (EMA), to capture fluctuations in thinking and affect in the flow of daily life experiences (e.g. Myin-Germeys, 2018; Shiffman, Stone, & Hufford, 2008). Studies using EMA have revealed a reciprocal relationship between rumination and affect, with rumination predicting negative affect at a subsequent measurement occasion, and negative affect predicting subsequent rumination to the same effect (Moberly & Watkins, 2008). They also show that a strong temporal relationship between negative affect and subsequent rumination is associated with heightened symptoms of depression and greater emotional inertia (Brose, Schmiedek, Koval, & Kuppens, 2015), that is the increased carry over of negative emotions from one moment to the next (Kuppens, Allen, & Sheeber, 2010).

We are not aware of any EMA studies that directly test the assumption that fluctuations in negative affect trigger rumination across time as a function of habit. Furthermore, the relationship of such habitual rumination with emotional inertia remains unclear. Given that habits might explain persistent patterns of rumination (Shaw et al., 2019), which in turn have been associated with greater emotional inertia (Koval, Kuppens, Allen, & Sheeber, 2012), it may be that habitually ruminating in response to negative affect contributes to more persistent negative mood states (i.e., greater inertia). Consistent with this, Brose et al. (2015) found that a strong temporal pairing of affect-rumination tended to co-occur with emotional inertia, such that individuals with heightened symptoms of depression tended to be characterized by both high levels of emotional inertia and a strong temporal pairing of affect-rumination. Finally, to our knowledge no study has assessed how habitual rumination relates to everyday levels of positive affect, which may be an important resilience factor that reduces momentary rumination (Hoorelbeke, Van den Bergh, Wichers, & Koster, 2019). Although failed resolution of goals has usually been associated with increases in negative affect, it is equally possible that it results in detrimental changes in the momentary experiences of positive affect, and that decreased levels of positive affect and ruminative thinking may be paired over time. In line with this, depression has not only been associated with greater levels of momentary negative affect but also decreased levels of everyday positive affect (Telford, McCarthy-Hones, Corcoran, & Rowse, 2012). However, the relevance of positive affect to the rumination process is relatively understudied and therefore not well understood, and the possible link between changes in positive affect and subsequent rumination therefore exploratory in nature.

1.1. The present study

The aim of the current study was to assess if the habitual characteristics of negative thoughts are related to the dynamic interplay between negative affect and ruminative thinking in the flow of daily life experiences. In line with vulnerability-stress models of depression (Abramson et al., 2002; Ingram & Luxton, 2005) and recent emphases on dimensional approaches to the study of mechanisms contributing to psychopathology (Kozak & Cuthbert, 2016), the study was conducted in a non-selected sample with a wide range of depressive symptoms. We utilized EMA wherein participants provide everyday 'in the moment' data about their immediate experiences when prompted by an alarm signal. Momentary affect and rumination were assessed multiple times during the day over a 6-day period, allowing for the assessment of their temporal relationships. As mentioned earlier, advantages of EMA are that it provides findings with high ecological validity (Shiffman et al., 2008) and virtually eliminates retrospective bias (Trull & Ebner-Priemer, 2013). Furthermore, imperative to the measurement of habits, EMA can evaluate fluctuations in affect and rumination over short temporal intervals, allowing researchers to investigate contingencies of which people may be unaware (Neal & Wood, 2009).

We tested two hypotheses derived from the habit-goal framework of depressive rumination (Watkins & Nolen-Hoeksema, 2014) and prior findings (Brose et al., 2015; Hoorelbeke et al., 2019; Moberly & Watkins, 2008). First, we expected increased negative affect to prospectively predict greater rumination-levels at the next sampling occasion. Secondly, because the habit-goal framework predicts that rumination can develop into a mood-linked habit, measures of habit should be specifically associated with the degree to which affect triggers rumination across time rather than just being associated with average levels of momentary rumination. We therefore expected the interplay between negative affect and rumination to be moderated by habit, with increased habitual characteristics of negative thinking predicting greater rumination in response to fluctuations in negative affect. To our knowledge this is the first direct empirical test of the relationship between the habitual characteristics of thought and the dynamic interplay between affect and rumination. We also explored if the same pattern of findings would be apparent when looking at the deterioration of positive affect as a possible trigger for momentary rumination. Finally, given that the temporal pairing of negative affect and rumination has been associated with emotional inertia (Brose et al., 2015) we also explored if habitual characteristic are associated with heightened emotional inertia during the EMA assessment.

2. Method

2.1. Participants

One hundred and fifteen students of various disciplines at the University of Iceland were recruited via an introductory e-mail sent out to all registered students. We requested volunteers for a study on depression vulnerability although we made it clear that participants did not have to be depressed to take part. As intended, we obtained a sample with a wide range of depressive symptoms as measured with the Beck Depression Inventory – II (range = 0–50, M = 14.9, SD = 10.1).

Inclusion criteria were an age between 18 and 65 years and being fluent in Icelandic. Due to technical difficulties seven participants were unable to participate and three dropped out of the study due to time limitations and had no valid responses. Of the participants, 106 completed the EMA measurements. Eight were subsequently excluded due to inadequate EMA compliance (fewer than 10 completed alerts), resulting in a final sample of 97 participants (24 males, 73 females; mean age 23.3 years; SD = 2.81). Participants were rewarded with the equivalent of €30 for their participation.

2.2. Measures

2.2.1. Trait-level questionnaires

2.2.1.1. The ruminative responses scale (RRS; Nolen-Hoeksema & Morrow, 1991). The RRS is a self-report measure of ruminative disposition which contains 22 items that assess a person's tendency to think about the symptoms, causes, and consequences of their depressed mood. The current study utilized the 5-item brooding subscale (RRS-B), which measures more passive, analytical and repetitive forms of thinking, and is thought to represent the maladaptive component of rumination (Treynor, Gonzalez, & Nolen-Hoeksema, 2003). The Icelandic version of the RRS has shown good psychometric properties (Pálsdóttir & Pálsdóttir, 2008). In the current study RRS-B had an $\alpha = 0.91$.

2.2.1.2. Habit Index of Negative Thinking (HINT). The habitual quality of negative thinking was measured with the HINT (Verplanken, Fribort, Wang, Trafimow, & Wolf, 2007), a 12 item self-report scale that measures the degree to which negative thoughts occur frequently, are initiated without awareness, are unintended, are difficult to control, and are self-descriptive. Each item is rated on a 7-point scale in response to the general prompt; "Thinking negatively about myself is something…". and included items such as "I do unintentionally" and "I start doing before I realize I'm doing it". The HINT thus taps the process aspects – the repetitive and automatic nature of the thoughts – which are considered as key elements of mental habits, and which can be distinguished from the content and valence of the thoughts themselves (Verplanken et al., 2007; Watkins, 2008). Evidence of discriminant validity between habitual negative thinking and rumination come from a series of studies by Verplanken et al. (2007) that found HINT to uniquely contribute to feelings of low self-worth over and above rumination, finding them to be related but empirically distinct. Furthermore, a commonality analyses by Gustavson et al. (2019) showed that although HINT shared variance with both rumination and worry in predicting symptoms of depression, HINT also accounted for considerable unique variance not attributable to either rumination or worry. The Icelandic version of the HINT has high internal consistency and good discriminant validity (Ólafsson, Jóhannesdóttir, Jóhannesdóttir, & Hjartarson, 2019). In the current study HINT had an $\alpha = 0.93$.

2.2.1.3. Beck Depression Inventory (BDI-II; Beck, Steer, & Brown, 1996). The BDI-II is a 21 item self-report questionnaire that measures the severity of depression symptoms during the past two weeks. The Icelandic versions of the BDI-II (Arnarson, Ólason, Smári, & Sigurðsson, 2008) has shown good psychometric properties. The BDI-II had an $\alpha = 0.91$ in the current study.

2.2.2. EMA measures

2.2.2.1. Negative and positive affect (NA/PA). Participants rated their current mood at each assessment during the EMA period. The choice of items was based on the widely used Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988) and previous EMA studies (revealing items with high loadings on NA and PA latent factors; e.g., Wichers, Lothmann, Simons, Nicolson, & Peeters, 2012). NA consisted of the following items: 1) *I feel sad right now*, 2) *I feel irritable right now*, and 3) *I feel guilty right now*. PA consisted of the items: 1) *I feel happy or cheerful right now*, 2) *I feel enthusiastic right now*, and 3) *I feel satisfied right now*. Participants responded using a five-point Likert scale from 1 (Not at all) to 5 (Very much). NA had an $\alpha = 0.71$ and was strongly correlated with BDI-II ($r = 0.54$; see Table 1) whereas PA had an $\alpha = 0.81$ and was negatively correlated with BDI-II ($r = -0.43$; see Table 1).[1]

2.2.2.2. Momentary Ruminative Self-Focus Inventory - abbreviated (MRSI-A). The MSRI is a 6-item questionnaire that measures state-level fluctuations in ruminative self-focus (Mor, Marchetti, & Koster, 2013). An abbreviated form (Connolly & Alloy, 2017) was chosen for use during the EMA period which contained three items: 1) *Right now, I am thinking about how happy or sad I feel*, 2) *Right now, I wonder why I react the way I do*, and 3) *Right now, I am thinking about the possible meaning of the way I feel*. Participants indicated their degree of rumination at the time of the alert using a 7-point Likert scale, from 1 (Strongly disagree) to 7 (Strongly agree). Both forms of the MRSI have shown excellent internal consistency and are correlated with alternative measures of rumination (Connolly & Alloy, 2017; Mor et al., 2013). In the present study, the MSRI-A had an $\alpha = 0.90$ and was moderately correlated with RRS-B ($r = 0.28$; see Table 1).[1]

2.3. Procedure

During an in-laboratory assessment session, participants completed the trait-level measures (BDI-II, RRS, HINT), were briefed one-on-one on the EMA procedure, and reviewed a sample EMA alert with the researcher to ensure proper understanding of the smartphone app and the sampling procedure. Beginning the following day after the in-lab assessment, participants were prompted by the smartphone app to answer 10 alerts per day for six consecutive days during a 12-h period (between 10 a.m. and 10 p.m.). Alerts were programmed according to a stratified semi-random interval scheme. Each day was divided into ten 72 min intervals, with a signal occurring randomly within each interval, with an average of 92 min between alerts. Each time, participants gave their momentary rating of rumination and affect (PA, NA, MRSI-A). Participants were instructed to answer given how they felt and thought "in the moment" and to complete the measures immediately upon receiving an alert. After receiving an alert, participants had 15 min to respond before it expired. Alerts were presented and responses collected using The Experience Sampler App (Thai & Page-Gould, 2017) an open-source smartphone app intended for ecological momentary assessment research (www.experiencesampler.com). Upon completing the EMA period, participants returned to the laboratory where they were debriefed and received compensation. This study is part of a larger multi-study research project that also included measures of emotion regulation and depression vulnerability that are reported elsewhere (e.g. Hjartarson et al., 2020).

2.4. Statistical analyses

Descriptive statistics were computed using R (R Core Team, 2018). Participants with fewer than 10 out of 60 completed alerts were excluded from the analyses.[2] Given the nested structure of the data (repeated assessments within individuals) we utilized Dynamic Structural Equation Modelling (DSEM) in Mplus 8.1, a multilevel approach to

[1] Correlations are based on within-person averages of NA, PA and MSRI-A.

[2] Previous research has shown that measures with less than 30% completed alerts may be less reliable (Delespaul, 1995). Our results remained virtually unchanged when using a more conservative criteria of at least 20 out of 60 valid alerts. We therefore present results based on a more inclusive sample in our analyses.

analysing EMA data (Hamaker, Asparouhov, Brose, Schmiedek, & Muthén, 2018; Muthén & Muthén, 2017). The models were run using Bayesian estimation with uninformative priors. We used 50.000 Markov Chain Monte Carlo iterations, of which every 10th was recorded for estimation purposes. A Bayesian approach is used in DSEM because it allows for simultaneous estimation of multiple dependent variables and, thus, is suited for examining cross-lagged models and bidirectional effects. Furthermore, it allows for the modelling of time-series data when the interval between measurements are of unequal distance (Schuurman, Ferrer, de Boer-Sonnenschein, & Hamaker, 2016). Another strength of DSEM is that it eliminates biases known to be associated with the use of lagged variables as predictors of autoregressive and other time-varying effects (i.e., Nickell's and Lüdtke's bias; McNeish & Hamaker, 2020).

In order to test our hypotheses, two successive multilevel models were computed, with either NA or PA as a measure of momentary affect. A visual representation of the models is presented in Fig. 1.

In both models, rumination (MRSI-A) and affect (NA/PA) at any given time-point (*t*) were predicted by rumination and affect at the previous time-point (*t-1*). We were interested in the effect of the variables on themselves (autoregressive paths) and on each other (cross-lagged paths). These associations were allowed to differ between individuals (i.e., random means and slopes). We tested whether habitual characteristics (HINT) predicted the strength of the person-specific autoregressive and cross-lagged relationships between rumination and affect. We follow Hamaker (2017), Hamaker, Asparouhov, & Muthén (2017), Hamaker et al. (2018) in presenting our models. The models decompose affect and rumination into latent within- and between-person components. The within-person components describe affect and rumination of individual *i* at time *t*:

$$Affect_{it} = \mu_{Affect,\,i} + \phi_{1i}\, Affect^{(w)}_{it-1} + \phi_{3i}\, Rumination^{(w)}_{it-1} + \zeta_{1it}$$

$$Rumination_{it} = \mu_{Rumination,\,i} + \phi_{2i}\, Rumination^{(w)}_{it-1} + \phi_{4i}\, Affect^{(w)}_{it-1} + \zeta_{2it}$$

where $\mu_{Affect,\,i}$ and $\mu_{Rumination,\,i}$ are the time-invariant (between-person) means of affect and rumination for individual *i*. The autoregressive parameters ϕ_{1i} and ϕ_{2i} represent the effect of the variables at *t-1* on themselves at time *t*. The cross lagged parameters ϕ_{3i} and ϕ_{4i} are the effects of the variables at *t-1* on each other at time *t*. The parameters ζ_{1it} and ζ_{2it} represent the residual variation at time-point *t* not explained by rumination and affect at the previous time-point *t*-1. Both the means μ_i and the lagged parameters ϕ_i are allowed to vary across individuals (hence the subscript *i*). We estimate the effect on HINT on these random effects on the between-level:

$$\mu_{Affect,\,i} = \gamma_{00} + \gamma_{01}\, HINT_i + u_{0i}$$

$$\mu_{Rumination,\,i} = \gamma_{10} + \gamma_{11}\, HINT_i + u_{1i}$$

$$\phi_{1i} = \gamma_{20} + \gamma_{21}\, HINT_i + u_{2i}$$

$$\phi_{2i} = \gamma_{30} + \gamma_{31}\, HINT_i + u_{3i}$$

$$\phi_{3i} = \gamma_{40} + \gamma_{41}\, HINT_i + u_{4i}$$

$$\phi_{4i} = \gamma_{50} + \gamma_{51}\, HINT_i + u_{5i}$$

where $\gamma_{00\text{-}50}$ is the fixed or group average of the parameters and u_i is the individual deviations from these effects. On the between level, HINT, denoted as γHINT, is included as a predictor of the person-specific means and person-specific autoregressive and cross-lagged associations. All the parameters were allowed to covary with each other. We report within-person standardized coefficients. In our models, statistical significance is based on the credible interval not containing zero (the default in DSEM). The corresponding Mplus code is included in the supplementary materials (Supplementary 1).

3. Results

3.1. Preliminary analyses

Participants completed a total of 2710 EMA alerts. Mean number of completed alerts was 33.1 (SD 11.4; range 10–53). See Table 1 for descriptive statistics. HINT was positively correlated with ruminative brooding (RRS), indicating that greater habitual characteristics are associated with a heightened ruminative disposition. On the other hand, HINT, was not correlated with average levels of momentary rumination. As we shall see, this is an example of how time-invariant means are ill-suited at capturing meaningful within-person variation across time.

3.2. Affect and rumination across time

The standardized effects and variances are presented in Table 2 and their corresponding paths are visualized in Fig. 1 [3]. Across both models, the autoregressive values (the effect of the variables on themselves) for NA (ϕNA→NA; B = 0.350) and PA (ϕPA→PA; B = 0.427) were significant, indicating carry-over (inertia) of both affective states from one moment to the next. The autoregressive effect for rumination (MRSI-A) was also significant for both models (ϕRum→Rum; Bs = 0.257 and 0.299) indicating that once initiated, rumination tended to persist.

The cross-lagged values (the effect of the variables on each other over time) revealed paths from affect to rumination, in both models, when controlling for initial levels of rumination (Table 2). The results show that individuals with heightened NA at one moment engaged in more rumination on the next measurement occasion (ϕNA→Rum; B = 0.118), and similarly, that a decline in PA was also predictive of greater rumination at the next measurement (ϕPA→Rum; B = −0.078). Thus, for both negative and positive affect, a within-person deviation from one's own mean level of affect was associated with a subsequent within-person change in rumination.

Surprisingly, no paths were found from rumination to either NA (ϕRum→NA; B = 0.038) nor PA (ϕRum→PA; B = −0.029) meaning that rumination did not predict subsequent changes in affect. [4] The significant variance components in both models (see Ψ values) revealed marked individual variation in all the effects (see Table 2).

The correlations between within-level effects are visualized in Fig. 2. Blue connections represent positive correlations, and red connections represent negative correlations. Individuals with a higher average level of negative affect tended to have more moment-to-moment carry-over in their negative affect. This is evident in the positive correlation (r = 0.187) between the mean μNA and the autoregressive parameter ϕNA→NA. We also observed that when people ruminated to a greater extent in response to heightened negative affect, there was more moment-to-moment carry-over in affect. This appears in the positive correlation (r = 0.109) between the autoregressive parameter ϕNA→NA and the cross-lagged parameter ϕNA→Rum. Also noteworthy, the negative correlation (r = −0.171) between the cross-lagged coefficient ϕNA→Rum and the autoregressive parameter ϕRum→Rum implies that when people ruminate to a greater extent in response to heightened negative affect, there tends to be less carry-over of rumination from one moment to the next. We also note the finding (although weaker) that less carry-over of rumination was associated with greater emotional inertia (ϕNA→NA and ϕRum→Rum; r = −0.044), suggesting that reactive

[3] Unstandardized model parameters are provided in supplementary materials 2.

[4] An analysis of the data revealed that rumination does predict subsequent changes in NA and PA when excluding the between-level predictor HINT. This is consistent with prior findings (e.g., Moberly & Watkins, 2008) showing rumination to predict subsequent changes in affect. However, when accounting for the effects of HINT, and associated parameters, other paths become more predominant.

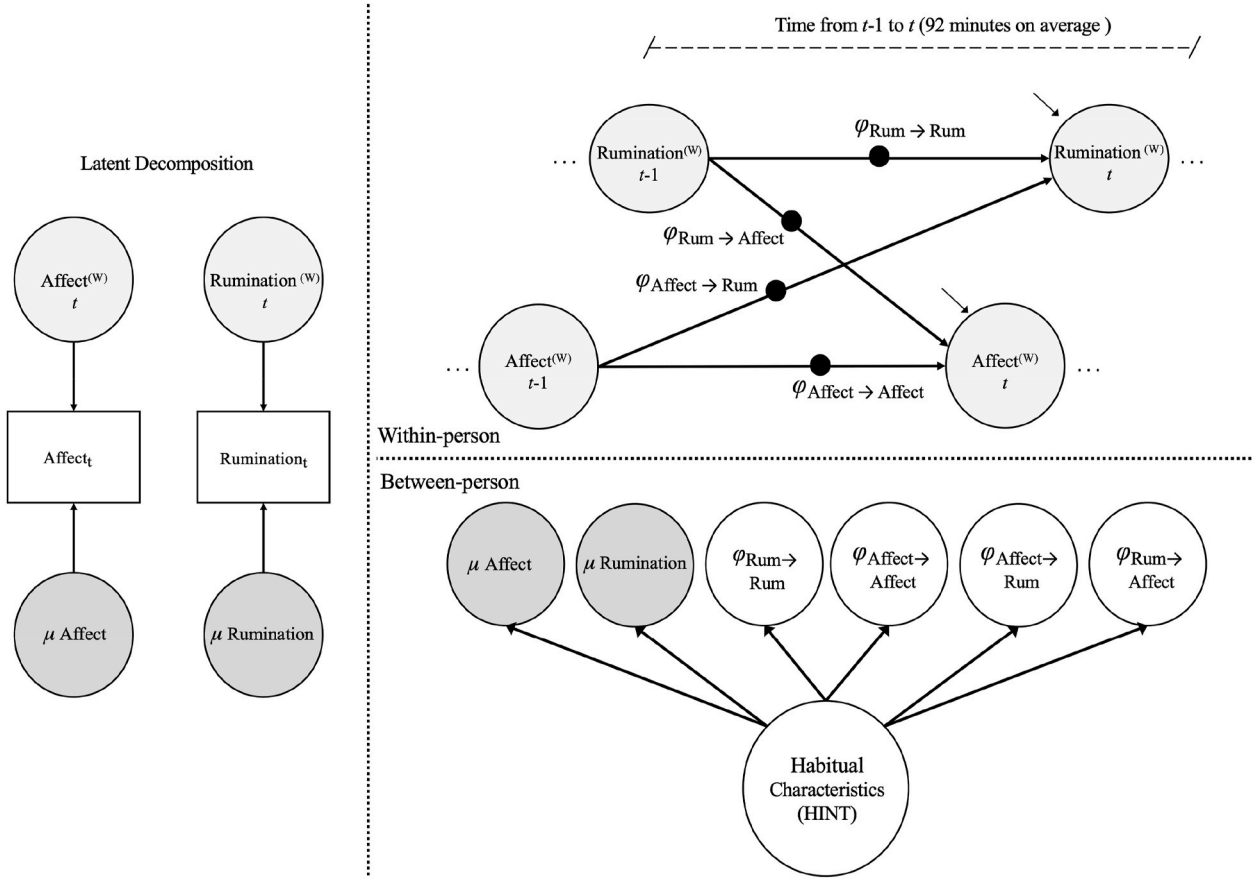

Fig. 1. Multilevel cross-lagged model estimating the effect of habitual characteristics of negative thinking (HINT) on the temporal association between momentary affect (NA/PA) and rumination (MRSI-A). Black dots indicate random effects. $^{(w)}$ represent within-person estimates.

Table 1
Descriptive statistics.

			1	2	3	4	5	6
Trait measures	1	Depressive Symptoms (BDI-II)		0.60***	0.61***	0.54***	−0.42***	0.21*
	2	Ruminative Brooding (RRS-B)			0.51***	0.44***	−0.34***	0.28**
	3	Habitual Characteristics (HINT)				0.55***	−0.32**	0.19
EMA measures	4	Negative Affect (NA)					−0.53***	0.28**
	5	Positive Affect (PA)						−0.03
	6	Momentary Rumination (MRSI-A)						
M			14.88	11.11	51.76	4.33	7.95	6.95
SD			10.08	3.40	16.82	0.80	1.58	3.02
Range			0–50	5–20	12–84	3–15	3–15	3–21

Note. Pearson correlation, $p < 0.001$ '***', $p < 0.01$ '**', $p < 0.05$ '*' (alpha = 0.05).
BDI-II = Beck Depression inventory; RRS = Ruminative Response Scale; HINT = Habit-Index of Negative Thinking; MRSI-A = Momentary Ruminative Self-Focus Inventory.

rather than static levels of ruminative thinking tend to be associated with greater emotional inertia. Also, greater mood-linked rumination was to some extent associated with preceding rumination having less effect on mood (ϕNA→Rum and ϕRum→NA; $r = -0.046$), suggesting that when mood-linked rumination is present, any ruminative thinking occurring prior to that tends to have a smaller effect on mood.

Finally, the dynamic parameters were less intertwined for positive than negative affect, with only one significant association (see Fig. 2). Mean μPA and the cross-lagged coefficient PA→Rum were negatively correlated ($r = -0.171$), suggesting that greater rumination in response to decreased PA was associated with lower average levels of positive affect.

3.3. Habitual characteristics and the relationship between affect and rumination across time

For negative affect, HINT was significantly associated with larger cross-lagged parameters (ϕNA→Rum; B = 0.217; see Table 2). This relationship is depicted in Fig. 3 which shows that when associated with greater trait habitual characteristics, a momentary increase in NA is more likely to evoke heightened rumination on the next measurement occasion. This effect corresponds to an increase of 0.015 (absolute value) in the cross-lagged parameter ϕNA→Rum for each point increase in HINT.

Also, for positive affect, HINT was significantly associated with larger (negative) cross-lagged parameters (ϕPA→Rum; B = −0.304). Fig. 3 shows that, for PA, larger negative coefficients can be found at the

Table 2
Habitual characteristics of negative thinking (HINT) predicting the reciprocal association between momentary affect (NA/PA) and rumination (MRSI-A) over time. Standardized effects.

	Negative Affect				Positive Affect		
	B	SD	95% CI		B	SD	95% CI
Means				Means			
μ NA	5.02*	0.54	[4.04, 6.20]	μ PA	4.48*	0.39	[3.73, 5.28]
μ RUM	2.07*	0.20	[1.69, 2.47]	μ RUM	2.06*	0.20	[1.68, 2.45]
Autoregression				Autoregression			
ϕ NA→NA	0.35*	0.03	[0.30, 0.40]	ϕ PA→PA	0.43*	0.03	[0.37, 0.48]
ϕ RUM→RUM	0.26*	0.03	[0.20, 0.31]	ϕ RUM→RUM	0.30*	0.03	[0.24, 0.35]
Cross-lagged slopes				Cross-lagged slopes			
ϕ NA→RUM	0.12*	0.03	[0.06, 0.18]	ϕ PA→RUM	−0.08*	0.03	[-0.13, −0.03]
ϕ RUM→NA	0.05	0.03	[-0.01, 0.10]	ϕ RUM→PA	−0.03	0.03	[-0.09, 0.02]
Effect of HINT on…				Effect of HINT on…			
μ NA	0.35*	0.07	[0.20, 0.48]	μ PA	−0.20*	0.07	[-0.34, −0.05]
μ RUM	0.11	0.07	[-0.03, 0.25]	μ RUM	0.12	0.07	[-0.03, 0.26]
ϕ NA→NA	0.16	0.09	[-0.01, 0.33]	ϕ PA→PA	0.09	0.10	[-0.11, 0.29]
ϕ RUM→RUM	−0.04	0.09	[-0.20, 0.13]	ϕ RUM→RUM	−0.02	0.09	[-0.19, 0.15]
ϕ NA→RUM	0.22*	0.09	[0.03, 0.39]	ϕ PA→RUM	−0.30*	0.12	[-0.53, −0.08]
ϕ RUM→NA	0.09	0.11	[-0.12, 0.31]	ϕ RUM→PA	0.03	0.15	[-0.28, 0.32]
Variances				Variances			
$\Psi\mu$ NA	0.88*	0.05	[0.77, 0.96]	$\Psi\mu$ PA	0.96*	0.03	[0.88, 1.00]
$\Psi\mu$ RUM	0.98*	0.02	[0.94, 1.00]	$\Psi\mu$ RUM	0.98*	0.02	[0.93, 1.00]
$\Psi\phi$ NA→NA	0.97*	0.03	[0.89, 1.00]	$\Psi\phi$ PA→PA	0.98*	0.02	[0.92, 1.00]
$\Psi\phi$ RUM→RUM	0.99*	0.01	[0.96, 1.00]	$\Psi\phi$ RUM→RUM	0.99*	0.01	[0.96, 1.00]
$\Psi\phi$ NA→RUM	0.95*	0.04	[0.85, 1.00]	$\Psi\phi$ PA→RUM	0.89*	0.07	[0.72, 0.99]
$\Psi\phi$ RUM→NA	0.98*	0.03	[0.91, 1.00]	$\Psi\phi$ RUM→PA	0.98*	0.03	[0.88, 1.00]

**significance is based on the Credible Interval (CI) not containing zero.*
Note. RUM = Momentary rumination (MSRI-A), NA = Negative Affect, PA = Positive Affect.

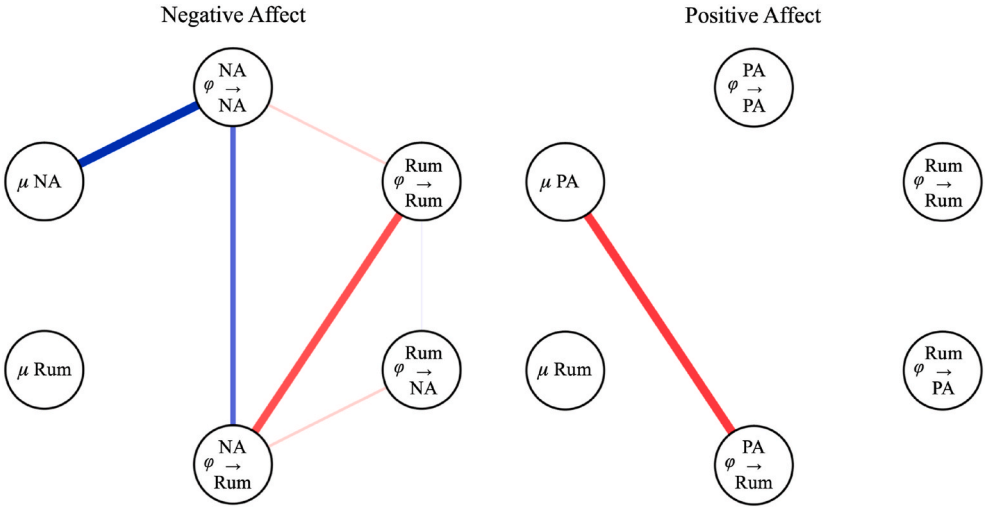

Fig. 2. The temporal relationship between momentary rumination (MRSI-A), negative affect (NA) and positive affect (PA). A visual representation of the correlations between means, autoregressive and cross-lagged parameters in the two models. Only correlations whose 95% credible interval did not include zero are included. Blue connections represent positive correlations and red connections represent negative correlations. The thickness of the lines indicate correlation strength. This correlation structure was created with qgraph in R (Epskamp, Cramer, Waldorp, Schmittmann, & Borsboom, 2012). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

higher end of the HINT distribution, thus, *a decrease in PA* is more likely to evoke heightened rumination on the next measurement occasion when associated with greater habitual characteristics. This corresponds to a decrease of −0.007 (absolute value) in the cross-lagged parameter ϕPA→Rum for each point increase in HINT. As evidenced by the standardized estimates, this effect was larger for PA than for NA.

Finally, HINT was associated with higher average levels of NA (μ = 0.345) and lower average levels of PA (μ = −0.197), indicating that when accounting for the temporal relationships, heightened habitual characteristics were associated with greater levels of NA and lower levels PA over the course of the EMA assessment period. HINT was not significantly associated with other parameters in the models.

We followed these results with additional analyses to investigate the robustness of our findings. The current findings remained unchanged when the results were detrended to control for the possible influence of time on the measurements.[5] Ruminative brooding, when entered at the between level instead of HINT in the models above, was not a significant predictor of the cross-lagged parameter ϕNA→Rum (B = 0.125; 95% CI = [-0.05, 0.29]) nor ϕPA→Rum (B = 0.018; 95% CI = [-0.21, 0.25]). Depression symptoms (BDI-II), however, were predictive of a greater cross-lagged parameter for ϕNA→Rum (B = 0.195; 95% CI = [0.03, 0.36]) but not for ϕPA→Rum (B = −0.082; 95% CI = [-0.30, 0.15]).

HINT, ruminative brooding, and BDI-II were moderately correlated in the present study (see Table 1). We therefore computed the above

[5] The time of measurement was inserted in the within-part of the models to control for trends or non-stationary of the data during the measurement period. The results remained unchanged for both models of positive and negative affect.

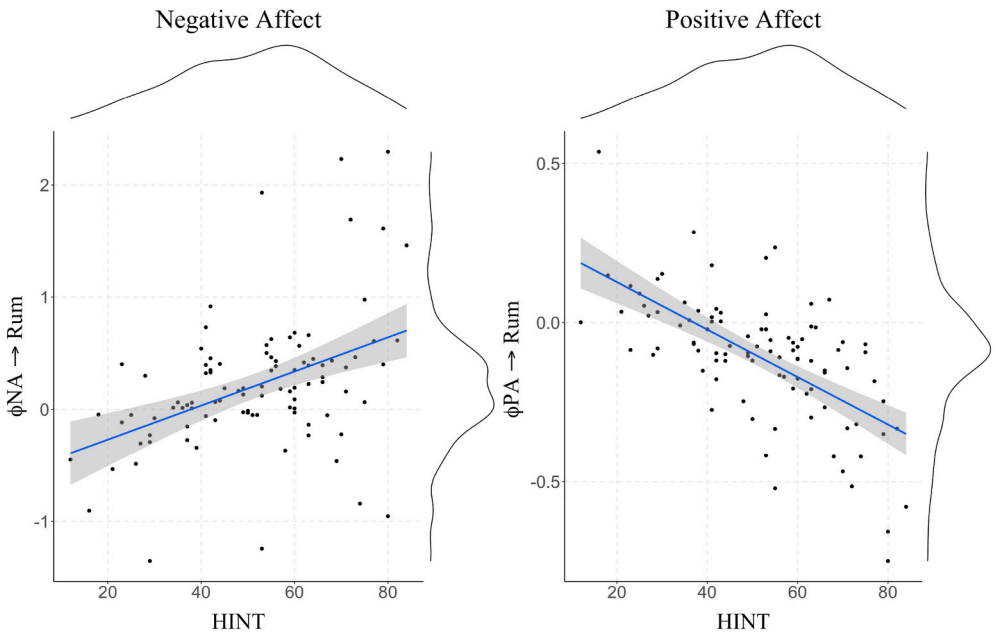

Fig. 3. Momentary negative (NA) and positive affect (PA) predicting rumination on the next measurement occasion given the individuals' habitual characteristics (HINT). Raw estimates of cross-lagged parameters ϕAffect→Rum for positive and negative affect are shown. Each dot corresponds to one participant. Marginal plots show density distributions for HINT and the cross-lagged parameters.

models again using the residual variance of HINT, when regressed on either ruminative brooding or BDI-II, to see whether the results depended on the shared variance between the measures. HINT (residualized by brooding) still remained a unique predictor of the cross-lagged parameters ϕNA→Rum (B = 0.154; 95% CI = [0.02, 0.31]) and ϕPA→Rum (B = −0.341; 95% CI = [-0.59, −0.10]). When accounting for depressive symptoms, HINT (residualized by BDI-II) still remained a unique predictor of the cross-lagged parameter ϕPA→Rum (B = −0.342; 95% CI = [-0.62, −0.09]) but not for ϕNA→Rum (B = 0.05; 95% CI = [-0.13, 0.24]).[6]

4. Discussion

The aim of the current study was to assess if the habitual characteristics of negative thoughts are related to the dynamic interplay between negative affect and ruminative thinking in the flow of daily life experiences. Momentary increased negative affect was prospectively associated with greater ruminative thinking at the next sampling occasion. This relationship was moderated by a measure of habitual characteristics of negative thinking, such that a stronger association was observed with greater levels of habitual characteristics (i.e., repetition, lack of conscious awareness and deliberate intent, mental efficiency, lack of control and self-descriptiveness). To our knowledge, this is the first explicit test of habit-goal framework of depressive rumination using mobile EMA assessment. These key findings replicate previous results (Brose et al., 2015; Moberly & Watkins, 2008; Ólafsson et al., 2020) and extend them by showing that negative affect can trigger ruminative thinking in everyday life as a function of habit.

These findings are consistent with the habit-goal framework of depressive rumination (Watkins & Nolen-Hoeksema, 2014) which conceptualizes rumination as a response triggered by context (i.e., negative affect) rather than intentions or goals. Because habitual characteristics specifically predicted the degree to which individuals ruminated in response to negative affect, and not just average levels of momentary rumination, this suggests that depression vulnerability may be in the form of rumination being habitually triggered by contextual factors (without conscious awareness and intent), making it difficult to control. The results held when accounting for the shared variance of HINT with a cardinal measure of depressive brooding, indicating that HINT taps aspects of habitual rumination not fully captured by traditional trait measures of rumination. Although the brooding subscale of the RRS has often been considered a measure of habitual rumination, it focuses on the frequency of ruminative processing since respondents are asked to rate how often they have certain ruminative thoughts when they feel sad or depressed (rated on a scale of repetition from "almost never" to "almost always; Treynor et al., 2003). Although habitual behaviours may frequently emerge, frequency alone does not mean that behaviour is habitual in itself (Verplanken, 2006; Wood & Rünger, 2016). Behaviour that is repeatedly performed in a stable context, may gradually become a habit, that is controlled by contextual cues, rather than mediated by goals or intentions. Thus, habitual behaviours are also characterized by a degree of automaticity (i.e., lack of conscious awareness and deliberate intent, mental efficiency, and lack of control; Neal & Wood, 2009). HINT is aimed to measure both the automaticity and repetition of negative thinking (Verplanken et al., 2007) and should therefore be associated with a measure of the context-response association between affect and rumination if it has become habitual. Consistent with this, the current study found that HINT was as a significant predictor of the temporal pairing between affect and rumination whereas the brooding subscale of the RRS was not. In our view, this underlines the additive value of considering habit-like automaticity of thoughts in the study of adverse consequences of ruminative thinking in daily life.

Interestingly, although not specified by the habit-goal framework, the same pattern was found when assessing daily fluctuations in positive affect, showing that a deterioration of positive affect can also serve as a contextual trigger for ruminative thinking. Repeatedly experiencing *a decline* in positive affect whilst ruminating (e.g., when one's goals are persistently thwarted) might over time turn the deterioration of positive affect into trigger for subsequent rumination. Although this novel finding may suggest that the habit-goal framework (Watkins & Nolen-Hoeksema, 2014) is relevant to a broader spectrum of emotional

[6] Full model results HINT (residualized) are provided in supplementary materials 3.

experiences, it should be interpreted with caution. Although negative and positive affect are assumed to be independent constructs (Watson et al., 1988), they are also strongly correlated (Green & Salovey, 1999). It may be that positive affect influences rumination partly through its overlap with negative affect. Using larger samples, it would be interesting to explore the relative contribution of negative and positive affect when investigating the habitual nature of depressive rumination. Furthermore, it can be argued that this finding might to some extent reflect the effects of positive rumination (i.e., savoring; see Li, Starr, & Hershenberg, 2017) which has been found to be associated with heightened levels of positive affect. However, a momentary decline in positive affect (rather than increased levels) was associated with greater rumination, that was associated with lower average levels of PA during the experience sampling period, indicating adverse effects of ruminative brooding rather than savoring effects of positive rumination.

According to the habit framework rumination only develops into a trait-like habit once negative affect and ruminative thinking are paired over time. It is therefore theoretically consistent to expect some to ruminate without engaging in habitual negative thinking and vice versa (Shaw et al., 2019; Watkins & Nolen-Hoeksema, 2014). Consistent with this, we found significant variation in the degree to which habitual characteristics of negative thinking were associated with the context-response association between momentary affect and rumination.

Although not the main objective of the study, we also examined how our findings related to symptoms of depression severity. It is when rumination turns habitual that it is hypothesized to be more detrimental for people's emotional well-being (Shaw et al., 2019; Watkins & Nolen-Hoeksema, 2014). Consistent with this, we found that people ruminate in response to daily fluctuations in negative mood as a function of depressive symptom severity. This suggests that once rumination has become contingent on the emotional context (i.e., negative affect) people also tend to experience more severe symptoms of depression. Furthermore, when accounting for the shared variance of HINT with depressive symptoms, habitual thinking was no longer a significant predictor of the temporal pairing between NA and subsequent rumination. Although we cannot exclude the possibility that this finding might to some extent reflect an overlap in negative content of the self-report measures, it is also in line with theoretical accounts of habitual rumination and might suggest that the link between habitual thinking and the dynamic interplay of affect-rumination at the microlevel overlaps with depressive symptomology in a meaningful way (Shaw et al., 2019; Watkins & Nolen-Hoeksema, 2014). Interestingly, this pattern did not emerge when looking at decreased positive affect as a trigger for everyday rumination. Habitual negative thinking remained a significant predictor even when accounting for depressive symptomology, suggesting that it may represent a less maladaptive form of ruminative process, consistent with dimensional approaches to psychopathology (Kozak & Cuthbert, 2016). However, since depressive symptoms were not measured repeatedly over time in our study design, inferences of causality are precluded. Future studies should address this constraint using prospective designs, and specifically test whether the interplay between mood-triggered rumination and habitual thinking serve as predictors of depression status over time, confirming its role as a vulnerability factor (e.g., in groups with a recurrent history of depression).

Habitual characteristics of negative thinking were not associated with emotional inertia (i.e., more carry over of mood from one moment to the next). Although not directly related, HINT was associated with the degree to which negative affect triggered subsequent rumination, which in turn was associated with greater levels of emotional inertia, as well as less carry-over of rumination from one moment to the next (see Fig. 2). Although speculative, it is possible that an indirect relationship exists wherein habitual attributes facilitate greater mood-linked rumination, which in turn leads to heightened emotional inertia. In comparison, ruminating in response to deteriorating positive affect did not involve the same detrimental dynamic process of emotional inertia. This indicates that people recover relatively quickly when ruminating in response to decreased positive affect whereas when they ruminate in response to negative affect, they tend to get 'stuck' in their current negative emotional state. The finding that greater NA-linked rumination was associated with reduced carry-over of rumination, suggests that once rumination has become contingent on negative mood, it tends to vary more over time. Indeed, previous research has found momentary rumination to vary considerably over time (Moberly & Watkins, 2008) and recent findings suggest that a greater history of depression may be associated with more variable levels of rumination (i.e., less carry-over; Bean, Heggeness, Kalmbach, & Ciesla, 2020). This is line with the habit-goal framework (Watkins & Nolen-Hoeksema, 2014) which posits that once habitual, negative mood states induced by processes other than perceived goal discrepancy could trigger rumination (e.g., watching a sad movie), extending the range of situations that cue ruminative thinking.

A particular strength of the study is the use of EMA assessment to capture rumination and affect in the flow of peoples' daily life experiences. This allowed us to test the effect of habitual characteristics on the temporal relationships between rumination and affect in an ecologically valid way (Myin-Germeys, 2018), which addresses limitations of previous studies (Verplanken et al., 2007; Ólafsson et al., 2020) restricted to trait measures of rumination. Crucially, we revealed a dynamic interaction between rumination and affect that would not have been apparent using trait measures alone.

This study also has limitations. Although we tested whether habitual characteristics influenced the strength of the temporal relationship between affect and rumination, the study does not address the developmental aspect of how rumination becomes habitual in the first place. According to the habit-goal framework (Watkins & Nolen-Hoeksema, 2014) situational factors that systematically thwart important goals and contribute to low mood (i.e., chronic stress and abuse) and person-specific factors associated with a lack of flexible responding (i.e., restricted coping repertoire and cognitive inflexibility) are hypothesized to facilitate the formation of rumination as a habit. Future research should aim to elucidate whether such situational and person-specific factors govern the strength the habitual association between affect and rumination. Furthermore, research should strive to assess whether the strength of the habitual association changes longitudinally as a function of such influencing factors. The EMA assessment methodology presented in the current study is ideally suited to test these novel predictions.

Another limitation has to do with the inference of causality. Although we found affect to influence rumination across time as a function of habit, it does not preclude other causal influences. Effect sizes in present study were generally moderate to small, indicating that other contributing factors might also cause affect to evoke a subsequent ruminative response. Further, there exist no reliable behavioural proxies to assess rumination as a habit. In the current study habitual qualities were inferred from self-report, limiting the inference of causality. Thus, the current findings highlight he need to clarify the unique role of habit in depressive rumination and the development of more specific behavioural measures of habitual rumination.

It must also be noted that although participants were specifically instructed to answer EMA questions in the moment based on how they felt just prior to the alert, the order in which EMA questions were presented was fixed. Items pertaining to affect were presented first preceding the rumination items, which could potentially prime a response for the rumination questions. Future research should address this potential shortcoming by utilizing varied or randomized item order designs.

Although the current study consisted of participants with a wide range of depression symptomology, it is unclear whether clinical depression differs dimensionally or categorically from non-clinical depression (Hankin, Fraley, Lahey, & Waldman, 2005). It is therefore

unclear if our findings would generalize to samples of individuals with a history of clinical depression. Majority of the sample were female students, limiting the generalization of the findings to males. We are working on replicating the current findings using a variety of experimental measures (see e.g. Hjartarson et al., 2020) and EMA assessment of rumination in diverse samples, including a history of clinical depression.

Our findings should be viewed in the context of the clinical relevance of the habit account of depressive rumination (Watkins & Nolen-Hoeksema, 2014). Interventions that modify individuals' beliefs and attitudes are unlikely to change habitual behaviours (Webb & Sheeran, 2006). Therefore, they may not be effective at changing habitual rumination, which could explain why rumination predicts a poorer response to standard cognitive-behavioural therapy (CBT; Jones & Siegle, 2008; Schmaling, Dimidjian, Katon, & Sullivan, 2002). Given that rumination has become contingent on the emotional context (i.e., negative or positive affect), preventive and acute therapy of depression needs to target the context-response association between affect and rumination, not just the *content* of the ruminative thoughts. The ruminative response needs to be replaced with a more helpful way of responding (e.g. concrete thinking, mindfulness, relaxation) to develop new context-response associations (Watkins & Nolen-Hoeksema, 2014; Wood & Neal, 2007).

Promising interventions include cognitive bias modification (CBM; Hertel, Holmes, & Benbow, 2014) and rumination-focused CBT (Watkins, 2018), that involve repeated training of alternative adaptive responses when faced with emotionally challenging situations. The findings of this study could be used to inform case conceptualization and treatment selection in future studies on the subject. We hypothesize that individuals with greater habitual rumination should respond more favorably to interventions such as CBM and rumination-focused CBT compared to individuals with less habitual rumination. Importantly, the EMA measurement strategy utilized in the current study could be used to test whether interventions are successful in reducing the habitual characteristics of the association between affect and rumination. This may provide information on the mechanisms of change during therapy and the predictive value of utilizing EMA measurement approaches in studying psychological well-being (see e.g. Dejonckheere et al., 2019).

5. Conclusion

The present results suggest that depression vulnerability may be in the form of rumination being habitually triggered in response to momentary fluctuations in affect, consistent with the habit-goal framework of depressive rumination (Watkins & Nolen-Hoeksema, 2014). Rumination may also be more detrimental when habitual because it leads to a greater persistence of dysphoric mood (i.e., emotional inertia) and more fluctuating levels of ruminative responding. To our knowledge, this is the first study to assess the role of habitual characteristics in the dynamic interplay between rumination and affect in daily life using EMA methodology. Our findings begin to outline how habits may emerge as a dynamic relationship between rumination and affect across time, that would not have been revealed with traditional trait measures alone. We hope that future research will expand on these findings and explore if assessing and targeting the habitual attributes of ruminative thinking can inform treatment selection and boost treatment response, thereby reducing suffering and depression vulnerability.

CRediT authorship contribution statement

Kristján Helgi Hjartarson: Conceptualization, Methodology, Software, Formal analysis, Writing – original draft, Writing – review & editing. **Ivar Snorrason:** Conceptualization, Writing – review & editing, Funding acquisition, Supervision. **Laura F. Bringmann:** Methodology, Formal analysis, Writing – review & editing, Supervision. **Bjarni E. Ögmundsson:** Software. **Ragnar P. Ólafsson:** Conceptualization, Methodology, Writing – original draft, Writing – review & editing, Funding acquisition, Supervision, Project administration.

Declaration of competing interest

The authors declare no conflicts of interest. The study was funded by research grants from the Icelandic Centre for Research (Grant Number 173803-051) and the Eimskip Fund of The University of Iceland.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.brat.2021.103832.

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