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RESEARCH PAPER

AN EXPERIENCE SAMPLING MEASURE OF THE KEY FEATURES OF RUMINATION

Yorgo Hoebeke, M. Annelise Blanchard, Alba Contreras, & Alexandre Heeren

Abstract

Objective: Research indicates that rumination can be viewed as a dynamic process that fluctuates over time, within hours and days. An increasing number of intensive longitudinal studies on rumination are accordingly being conducted and published using experiencing sampling methodology (ESM), a technique with measurements in everyday life. Yet, this literature suffers from a profound caveat: rumination has so far been conceptualized and measured as a unitary construct in these ESM studies. This is unfortunate, since such a unitary view contrasts with prominent contemporary models that regard rumination as a multifaceted construct, wherein the key features are not interchangeable and should therefore be measured separately. Moreover, no validated ESM measure of the key features of rumination has yet been developed. Therefore, we developed and validated an ESM protocol and the first ESM questionnaire to assess rumination as a multifaceted construct, measuring five features of rumination.

Method: We conducted an ESM study in a community sample of 40 French-speaking participants. They answered the five rumination ESM items in French four times a day for fourteen days. At the end of the ESM assessment period, participants completed trait-like questionnaires of rumination, depression, and general anxiety.

Results: The ESM rumination items exhibited good psychometric properties, including excellent within-person variability and convergent validity with corresponding trait-like constructs.

Conclusions: Although further validation is warranted, this novel ESM assessment protocol of rumination as a multifaceted construct (validated in French and translated into English) will allow future researchers to study how rumination's features fluctuate and interact with other constructs over time.

Key words: rumination, state rumination, experience sampling methodology, intensive longitudinal studies, psychometrics, daily life assessment

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Rumination consists of repetitive negative thoughts about one's concerns, sensations, feelings, and their implications, without taking any problem-solving action (Nolen-Hoeksema, 1991). Although mostly treated as a stable trait-like construct (Nolen-Hoeksema & Davis, 1999), recent research indicates that rumination might

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be better conceptualized as a dynamic process that fluctuates over time (e.g., Fang et al., 2019; Marchetti et al., 2018). In the last two decades, the study of the dynamics and fluctuations of psychological processes has been facilitated through the advent of technology and ecological approaches such as the Experience Sampling Methodology (ESM; Csikszentmihalyi & Larson, 1987). ESM allows for the acquisition of intensive longitudinal data (also called time-series data) and consists of measuring variables of interest daily or multiple times a day using various devices such as electronic diaries, watches, or smartphones (Hektner et al., 2007; Myin-Germeys et al., 2009). Researchers can thus capture the moment-to-moment fluctuations of their variables of interest with increased reliability and ecological validity (Hektner et al., 2007).

This growing interest in the daily study of psychological constructs has also become apparent in rumination research, as many ESM studies have begun to investigate the temporal fluctuations of rumination. For instance, ESM studies have revealed that an increase in negative affect (e.g., Hoorelbeke et al., 2016; Moberly & Watkins, 2008; Takano et al., 2011) and a decrease in positive affect (e.g., Brans et al., 2013; Hoorelbeke et al., 2016; Huffziger et al., 2013) often follows moment-to-moment increases in rumination. More recently, Faelens et al. (2021) found that Facebook use adversely predicted psychological processes (e.g., increased rumination), negative affect predicted more rumination at the next time-point, and rumination predicted negative affect at the next time-point as well (but to a lesser extent). Hjartarson et al. (2021) also found that negative affect predicted subsequent changes in rumination (increased negative affect leading to increased rumination), although they did not find evidence for the inverse relationship. In summary, ESM research has allowed researchers to explore the temporal fluctuations of rumination in more detail and thus shed light on its association with other variables.

Despite their contribution to the understanding of the dynamic nature of rumination, most of these ESM studies conceptualized rumination as a unitary construct; that is, they measured rumination via a single item or through a sum score of several self-report items (e.g., Faelens et al., 2021; Fang et al., 2019; Hjartarson et al., 2021). This is problematic since previous research and various models have pointed to distinct features of rumination, although there is no consensus regarding the exact number of features encompassing rumination. According to one of the most prominent models of rumination, the Response Styles Theory, there are at least five key constitutive features (Nolen-Hoeksema, 1991; Nolen-Hoeksema et al., 2008): namely, perseveration (the extent to which one repeatedly thinks about the same events, experiences, themes), brooding (the extent to which one thinks about the causes and consequences of their emotional state or emotional experiences), negativity (the extent to which one's thoughts are negative), self-criticism (the extent to which one criticizes themselves), and replaying (the extent to which one replays parts of events in their mind). Prior cross-sectional laboratory research has emphasized the added value of assessing these five features separately—via a specific item for each of the five features (e.g., Bernstein et al., 2017; LeMoult et al., 2013).

Moreover, in line with conceptualizing rumination as a multifaceted construct, research has shown that the five features proposed in the seminal work of Nolen-Hoeksema (Nolen-Hoeksema, 1991; Nolen-Hoeksema et al., 2008) can be viewed as nodes interacting within a complex network system (Bernstein et al., 2017, 2020). Indeed, by applying network analysis, these studies revealed for the first time the non-interchangeability of these features (e.g., Bernstein et al., 2017; Bernstein et al., 2020)—that is, though strongly interrelated, each feature was predictive of and predicted by the other ones in a unique fashion. Beyond emphasizing the relevance of distinguishing these features, these results thus suggest that each of the five features may serve a functionally distinct role and interact in a unique fashion with the other ones (e.g., the more one criticizes oneself for failures, the more likely one is to brood about how sad one feels).

However, despite these promising conceptual and empirical developments, these prior studies aiming to break down rumination into its distinct components all relied on cross-sectional data. Additionally, none of the ESM studies on rumination considered the various features of rumination (e.g., Faelens et al., 2021; Fang et al., 2019; Hjartarson et al., 2021), thus thwarting any inferences regarding the specific temporal unfolding of rumination's features. This current state of the literature on rumination is unfortunate, since enabling a temporal analysis of the five features of rumination would have at least three benefits. First, intensive longitudinal data would allow researchers to study how five hallmark features of rumination following Nolen-Hoeksema's theory (2008) unfold over time. Second, intensive longitudinal data will enable the application of several analysis methods. One promising approach that has gained traction in the last few years is temporal network analysis (for a review, Blanchard et al., 2022). Such explorations could give us insight into how these five distinct components trigger one another within participants over time while simultaneously investigating between-subjects associations. From this perspective, researchers could study how these variables self-predict from one time-point to another (i.e., autoregression) and predict one another (i.e., cross-lagged regression). Moreover, inspired by research on critical transitions in ecosystems (e.g., Hirota et al., 2011), one can also use intensive longitudinal data to grant clinical insight into whether someone is about to tip into a disordered state (e.g., development or relapse of psychopathology) or return to an ordered one (e.g., recover; for more detail, see Wichers et al., 2016, 2019). Finally, one can also use intensive longitudinal data to generate idiographic (i.e., specific to a single person) network models depicting how distinct variables of interest influence one another over time within one person. Idiographic networks can thus grant information about potential clinical pathways at play for a single person (Bastiaansen et al., 2020), thereby opening up radically new vistas for quantitative individualized case conceptualization and personalized therapeutic strategies (Fisher et al., 2017; Fisher & Bosley, 2020).

Unfortunately, to the best of our knowledge, no validated ESM tool allows researchers to assess rumination's features over time. We therefore propose the first ESM measure dedicated to capturing the temporal nature of the five features of rumination. As argued elsewhere (Blanchard et al., 2021), developing ESM items widely departs from creating a traditional (single time-point or "trait") questionnaire and comes with its specific challenges. For instance, ESM surveys should be extremely brief, taking a maximum of two to three minutes to complete, since participants will be taking time from their daily lives over weeks or months to answer these questions (Eisele et al., 2022; Kimhy et al., 2012; Myin-Germeys et al., 2018; Varese et al.,

2019). Next, questions should not feature too many repetitive items since participants already answer the same questions repeatedly, and participants often find answering similar items frustrating and confusing (Myin-Germeys & Kuppens, 2021). Some researchers therefore suggest employing single-item measures for straightforward unidimensional constructs (Robins et al., 2001; Wanous et al., 1997). Moreover, ESM items should be expressed in "colloquial" rather than technical terms so that they more closely mirror how individuals describe their daily life experiences (Myin-Germeys & Kuppens, 2021). One should therefore be extremely careful about the wording when developing ESM items (Myin-Germeys & Kuppens, 2021). In addition to careful phrasing, ESM studies need to find a balance between measurement frequency, measurement duration (i.e., the time required to answer an ESM questionnaire), and participants' burden, while also ensuring that the chosen measurement frequency adequately assesses the targeted constructs (Myin-Germeys & Kuppens, 2021). For example, asking about a participant's sleep quality three times a day is excessive; asking about a participant's appetite three times a day, however, would be suitable if timed around mealtimes. These requirements for developing optimal ESM items have rendered the assessment of their validity and reliability remarkably difficult (for an accessible overview of test reliability and validity concepts, see Jhangiani et al., 2019).

Despite these challenges, it is possible to assess the validity and reliability of ESM items by using methods appropriate for state measures. To this end, multi-level reliability, which evaluates both between- and within-person reliability, can be used to examine whether the ESM items cohere into a scale assessing the same overall construct (Cranford et al., 2006; Shrout & Lane, 2012). At the most straightforward level, one can evaluate the content validity of ESM reports by examining whether internal experiences make sense together (i.e., theoretically similar states would correlate, Eisele et al., 2021; Hektner et al., 2007). One can also examine convergent and discriminant validity by correlating ESM measures with similar and different constructs (Eisele et al., 2021). Since ESM items aim to capture fluctuations, it is also necessary to ensure that item responses have sufficient within-subject variability. To do so, one can examine each item's within-person standard deviation and intraclass correlation coefficients (ICCs; Trull & Ebner-Priemer, 2020), representing the proportion of the total variance due to between-person variance (Snijders & Bosker, 1999).

Following the above guidelines, we thus had two primary goals for the current project. First, we sought to develop an ESM tool (in both French and English) to assess five features of rumination. Since evaluating the reliability and validity of ESM measures is challenging, it is vital that the item-development phase results in self-explanatory and unambiguous items (i.e., high face validity) while covering all aspects of the construct (i.e., high content validity). We therefore carried out an iterative item development process, which included adapting items from existing one-time questionnaires into comparable measures of momentary state constructs. We developed the items in French and then back-translated them into English (see section "ESM Items & Protocol Development").

Second, inspired by recent ESM item development research (e.g., Blanchard et al., 2021), we wanted to investigate how the ESM items performed when administered to a community sample over fourteen days. To this end, we probed whether our newly developed items yielded sufficient within-person variance (i.e., low ICCs) and whether they had good convergent validity with trait-like questionnaires assessing similar constructs (see section "ESM tool psychometric properties"). If we met these goals, we wanted to share our resulting ESM items, administration methods, and all materials in an open science fashion (see below). We believe such an approach can foster further research on the temporal dynamics of rumination, facilitate direct comparisons between different studies, and provide the scientific community with a validated set of ESM items to measure the five key features of rumination over time.

Method

ESM Items & Protocol Development

ESM Rumination Items

To develop our ESM protocol on the features of rumination, we adapted items from previous research using a one-time measure (Bernstein et al., 2017; LeMoult et al., 2013) based on Nolen-Hoeksema's research (1991; Nolen-Hoeksema et al., 2008) and translated them into French[1]. The resulting ESM items consist of five items referring to each of the following five features of rumination: brooding, perseveration, replaying, negativity, and self-criticism. In particular, we reformulated the brooding and perseveration items to be more broadly applicable and more closely reflect the definition of brooding and the repetitive nature of thoughts, respectively.

Since rumination is not bound by set times or schedules but could occur at any time of the day, we tested two different prompt frequencies (four or five times a day) and, based on participants' feedback, chose four times a day (for more details about these initial pilot studies, see the supplementary materials available at https://osf.io/wj6xn). We strictly separated the four assessments by four hours (i.e., 9 AM, 1 PM, 5 PM, and 9 PM) in the validation study. This time equidistance is required for many multi-level statistical analyses (Epskamp et al., 2017). Additionally, according to participants' feedback, these scheduled time-points struck a balance between not starting too early in the day and not ending too late; they were also flexible enough for a broad population. Lastly, we used a back-translation procedure to translate the French ESM items (and their explanation) to English (see **table S1** in the supplementary materials at https://osf.io/wj6xn for the English version of the items as well as the explanation of the items provided to participants). First, a native French speaker who was fluent in English translated the ESM items from English to French. Then, two native English speakers who were fluent in French translated the French items into English, with any discrepancies between the two translations resolved through discussion.

ESM Protocol Development

We wanted to create an ESM protocol using open-

[1] The authors of this paper translated and adapted the items from Bernstein et al. (2017) and LeMoult et al. (2013); we discussed the phrasing of each item to ensure they would fit an ESM study. In addition to adapting and translating the items, we also developed a short explanation for each item to ensure participants correctly understood their meaning.

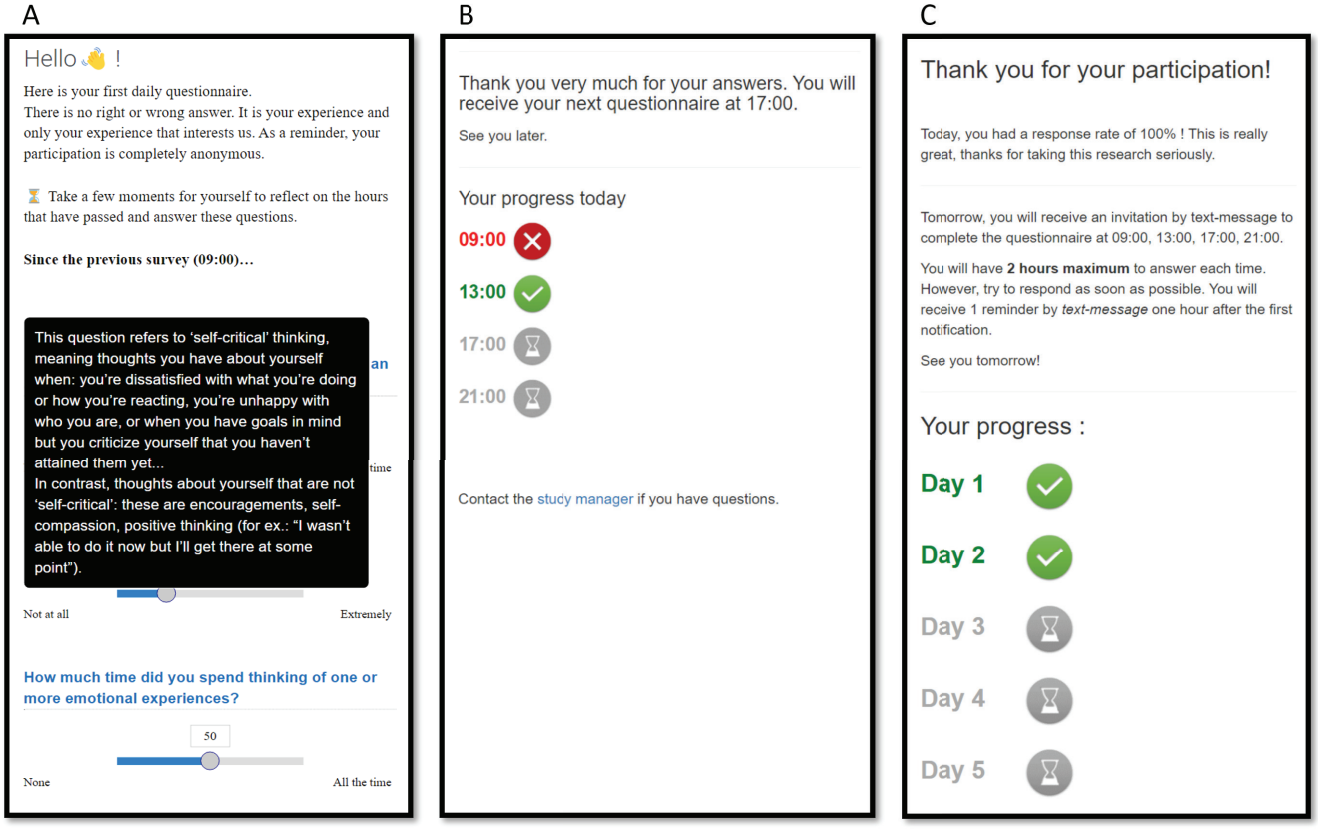
Table 1. *Descriptive Statistics of the ESM Items*

Variable	Item	*M*	*SD*	*Min*	*Max*	*ICC*
Perseveration	How much time did you spend thinking of one or more emotional experiences?	37.53	13.71	6.06	71.15	0.24
Negativity	To what extent were your thoughts negative?	27.76	13.48	0.00	62.49	0.26
Criticism	To what extent were your thoughts self-critical?	29.16	15.45	0.00	57.93	0.35
Brooding	How much did you think about the causes and consequences of emotional experiences?	33.95	14.07	5.72	67.49	0.25
Replaying	To what extent have you mentally replayed emotional experiences that you've had?	35.14	13.64	5.74	66.85	0.23

Note. This table contains the final ESM items in English (back-translated from the French items). The French ESM items can be found in the supplementary materials. *M* = within-person mean; *SD* = within-person standard deviation; ICC = Intraclass Correlation.

source software at a low cost. To this end, we used *formr* (Arslan et al., 2019) to collect sociodemographic and trait self-report data, and execute the ESM protocol. *Formr* (https://formr.org) is a software and study framework that allows researchers to create complex longitudinal surveys using R (R Core Team, 2022). It encourages open source practices by making studies easy to replicate (as the code for a specific study can be easily shared; see https://osf.io/dngyk/ for the code and instructions). Moreover, we chose to use *formr* because it is a web-based software: the surveys can be answered on any device with a web browser, ensuring compatibility with most of today's smartphones regardless of their operating system or brand. Another benefit of using *formr* is the extensive customization possible that allowed us to optimize our ESM protocol for compliance and optimal user experience (see the supplementary materials section available at https://osf.io/wj6xn). For instance, we customized the visual appearance of the survey and included "tooltips" (i.e., text boxes with explanations about an item, available at any time upon clicking on a question; see **figure 1**). Lastly, *formr* allows surveys to be sent through two main methods: email or text message. From our two pilots, we concluded that sending

Figure 1. *Screenshots of the ESM Protocol Created Using Formr*



Note. A: The ESM survey with a tooltip showing up; B: the screen once participants submitted an ESM survey during the day; F: End of the second day. Participants can see their progress throughout the study, and an encouragement message shows up on top depending on the day of the research and their response rate for the day.

Table 2. *Descriptive Statistics of Trait Questionnaires*

Questionnaire	*M*	*SD*	*Median*	*Min*	*Max*	Range	Cronbach's α
GAD-7	13.25	3.81	13.50	7	23	16	0.76
BDI-II	32.80	6.90	32.00	22	55	33	0.82
Brooding	10.90	3.18	11.00	6	20	14	0.73
Reflection	9.48	2.94	9.00	5	20	15	0.71
RRS-10	20.38	5.09	21.00	11	32	21	0.77
STAI-T	45.30	11.49	44.50	26	67	41	0.92

Note. GAD-7 = general anxiety symptoms; BDI-II = depression symptoms; Brooding = brooding subscale of the RRS; Reflection = reflection subscale of the RRS; RRS-10 = comprises the brooding and the reflection subscales; STAI-T = trait anxiety.

text messages was the most convenient option for the participants of this study.

ESM Tool Psychometric Properties

Participants

We gathered the ESM data between February 26th, 2021 and June 8th, 2021. Forty participants were recruited through social media (77.5% female; mean age = 21.2, *SD* = 2.03, min = 18, max = 26). To be included in the study, participants had to: be between 18 and 60 years old, be right-handed, speak French, and own a smartphone capable of opening web links to complete the survey. All participants provided written informed consent. The project received the approval of the Bio-medical institutional review board of UCLouvain (REF# 2020/057). Participants received 50€ for their participation in the study.

Measures

Self-report Trait Questionnaires. We administered the Beck Depression Inventory (BDI-II; Beck et al., 1996), the Generalized Anxiety Disorder scale (GAD-7; Spitzer et al., 2006), the Trait Anxiety Inventory (STAI-T; Spielberger et al., 1983), and the Ruminative Response Scale (RRS; Treynor et al., 2003) to assess convergent validity with trait-like proximal constructs. The BDI-II is a 21-item self-report questionnaire that measures symptoms of depression. The GAD-7 is a 7-item self-report questionnaire assessing generalized anxiety disorder symptoms. The STAI-T is a 20-item self-report questionnaire assessing proneness to anxiety. The RRS is a 22-item self-report questionnaire that measures the tendency to ruminate in response to negative affect or mood. Because half of the RRS items are related to depression, the five items corresponding to the "brooding" subscale and the five items corresponding to the "reflecting" subscale were used separately from the symptoms referring to depression (RRS; Treynor et al., 2003). We used the validated French versions of the scales (BDI-II; Beck et al., 1996; STAI-T; Bruchon-Schweitzer & Paulhan, 1993; RRS; Douilliez et al., 2018; GAD-7; Micoulaud-Franchi et al., 2016). We computed the total scale score for each scale, with higher score values denoting worse symptomatology (see **table 2** for descriptive statistics of the trait questionnaires). The participants answered these questionnaires at the end of the ESM procedure so that their answers could reflect their experience over the prior two weeks, thereby overlapping with the ESM period.

The ESM items. The ESM survey included the five rumination items discussed above[2]. We initially developed these items in French (see **table S1** in the supplementary materials at https://osf.io/wj6xn) and then translated them into English. **Table 1** depicts the English back-translated version of the items. Participants answered ESM items using a continuous scale from 0 ("Not at all") to 100 ("Absolutely") to ensure sufficient variability in responses and following previous research (e.g., Aalbers et al., 2019).

Procedure

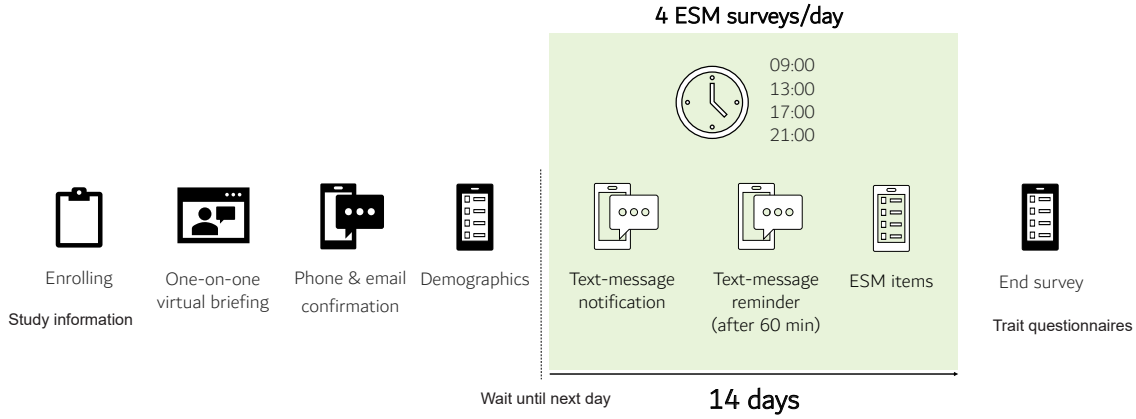
Participants were enrolled in the study asynchronously to allow for continuous recruitment. We kept track of the number of participants and their completion rate weekly, and we stopped recruiting participants once we reached 40 participants[3] with at least a 70% completion rate. After a virtual individual briefing session (for details, see the supplementary materials section at https://osf.io/wj6xn), participants answered demographic questions on their phones and then saw a screen reminding them about the ESM procedure explained during the briefing. The ESM assessment period automatically started the next day. We used a time-contingent sampling scheme with fixed intervals: participants were prompted four times a day (at 9 AM, 1 PM, 5 PM, and 9 PM) for fourteen days. At each prompt time, participants received a text message containing a personalized hyperlink to the ESM survey. Participants received an automatic reminder after one hour if they had not yet answered the survey, and they had two hours maximum to open the questionnaire following this initial notification (see the supplementary materials at https://osf.io/wj6xn for additional details about the timeout of the surveys). Moreover, a few days into the ESM period, the first author of this study called participants at a previously agreed-upon time and day to ask whether they had any questions or encountered any issues. Lastly, after submitting each ESM survey, the participant saw a screen showing how many questionnaires and days were left in the study (see **figure 1**).

After the two weeks of ESM prompts, participants completed the BDI-II, the GAD, the STAI-T, and the RRS. We also invited them to answer a survey about the ESM questions and how they experienced the ESM study (details are available in the supplementary materials at https://osf.io/wj6xn). We used a Qualtrics form to recruit participants for our research and verify inclusion and exclusion criteria. To collect the demographic, ESM, and trait self-report data, we used

[2] Note that we also included two additional items assessing self-report executive control and self-report absorption in an activity. We included this additional assessment in the context of a larger project not reported here.

[3] Please note that this approach is possible given the formr.org survey framework, which allows access to participants' answers and progress while the study is ongoing.

Figure 2. *Schematic Representation of the ESM Procedure*



formr (Arslan et al., 2019). **Figure 2** summarizes the entire study's protocol.

Statistical analyses

We assessed whether the item responses yielded sufficient within-subject variability and whether they showed convergent validity (i.e., how the ESM items correlated with the scores of trait questionnaires answered at the end of the ESM period; Hektner et al., 2007). We carried out all analyses using R 4.1.2 (R Core Team, 2022). Our R code and de-identified data are available at https://osf.io/dngyk/.

We computed the intraclass correlations (ICC) for every variable using intercept-only multi-level models (Gabriel et al., 2019) to assess whether the item responses yielded sufficient within-subject variability. The ICC represents the proportion of the total variance due to between-person variance (Snijders & Bosker, 1999); for example, an ICC of 0.8 indicates that 80% of the variance is due to the between-person variation and 20% to the within-person variation. For ESM research, it is recommended to have items with ICCs below 0.5, and ICCs values between 0.2 and 0.4 are common for ESM studies (Bolger & Laurenceau, 2013). This would indicate that an item has sufficient within-subject variability and that it is sensible to measure it frequently (Eisele et al., 2021). We also report the intraindividual means and standard deviations, following the recommendation of Trull and Ebner-Priemer (2020). Next, we examined the correlation table of all ESM items (within-person means for the ESM period) and trait questionnaires (general anxiety, rumination, and depression). We expected to observe moderate meaningful correlations in line with expected convergent validity (Eisele et al., 2021) despite the differences in assessment type (within-person vs. between-person) and assessment period between the ESM items (four times a day during two weeks) and the trait questionnaires.

Results

The overall compliance rate was 92.05%. Participants took a median time of 50 sec to answer[4] the ESM surveys (M = 2 min 25 sec, SD = 9 min 10 sec) and a median time of 15 min 35 sec to open the ESM surveys (M = 29 min 24 sec, SD = 31 min 18 sec; see **figures S1** and **S2** in the supplementary materials available at https://osf.io/wj6xn). Moreover, there were two peaks in the opening frequency of the surveys: one shortly after the initial prompt and a second smaller peak after 60 minutes (i.e., after the reminder; see **figure S2** in the supplementary materials available at https://osf.io/wj6xn).

Reliability

All items' ICCs were below 0.4 and thus showed sufficient within-subject variability (**table 1**).

Convergent/divergent validity

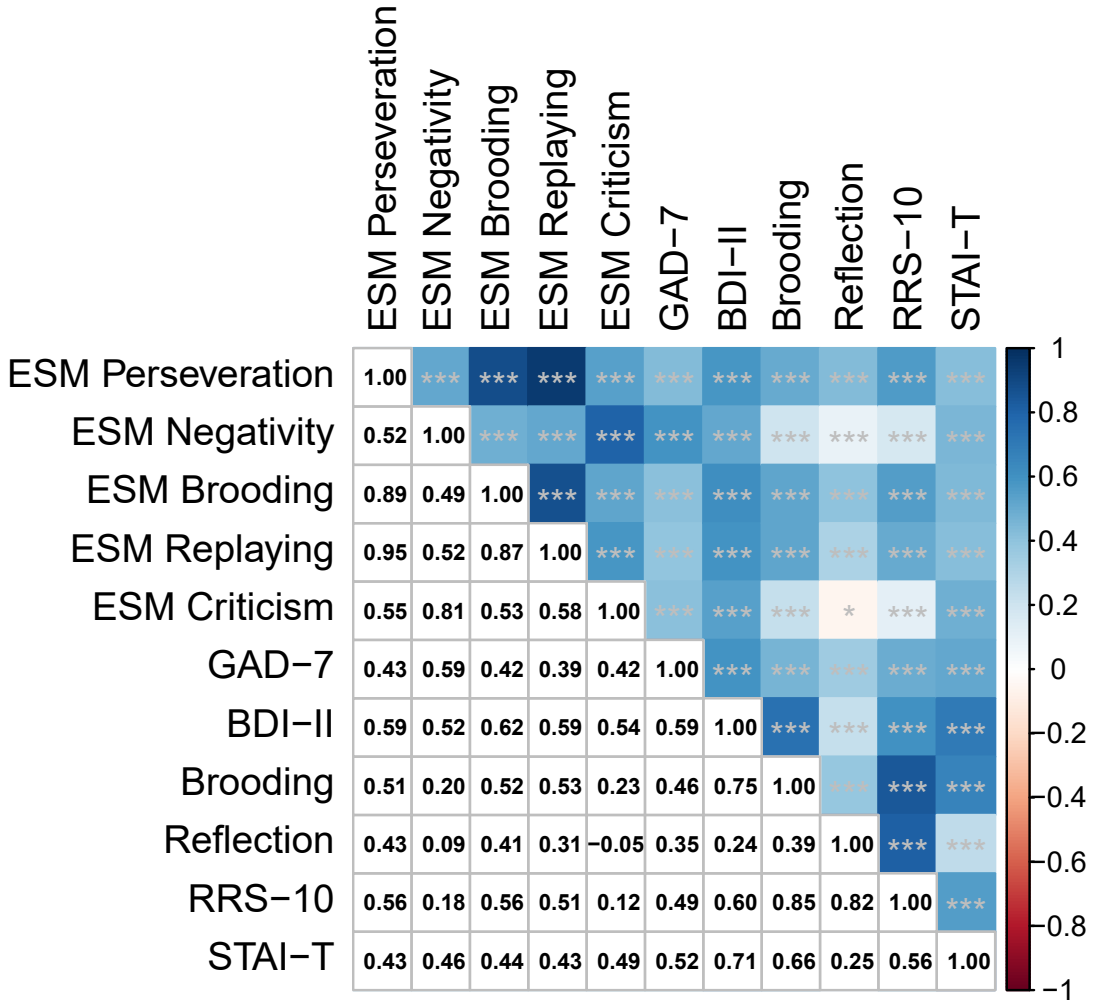
Correlations between trait questionnaires (GAD-7, BDI-II, STAI-T, and RRS) and the within-person means of the ESM items were significant ($p < .001$) and in the expected directions (see **figure 3** for a correlation matrix). Interestingly, all rumination ESM items except "negativity" were more strongly correlated with depression symptoms (BDI-II) than anxiety symptoms (GAD-7, STAI-T). Moreover, the correlations between all ESM items and the BDI-II were higher than the correlations between ESM items and the RRS-10 (comprising only items related to rumination). Lastly, negativity and self-criticism—the only two ESM items with an explicitly negative connotation—had low and significant correlations with the "reflection" subscale of the RRS (reflection-negativity: r = 0.09, $p < .001$; reflection-criticism: r = -0.05, $p < .05$): this could indicate adequate discriminant validity as the reflection subscale of the RRS is considered to measure adaptive thinking patterns.

Participants' experience

Participants' feedback regarding the ESM

[4] We removed one observation from the dataset since the participant submitted their answer 289 minutes after the initial prompt. Moreover, four surveys have been opened more than 120 minutes after the set time-points for alerts (9 AM, 1 PM, 5 PM, and 9 PM). We did not remove these observations because these delays were due to some bugs faced with *formr's* internal timing of the alerts, which induced delays from time to time (e.g., the first alert was sent at 9:25 AM instead of 9:00 AM). Hence, we decided to keep these observations.

Figure 3. *Correlation Plot of All ESM Variables (Within-Person Means) and Trait Questionnaires*



Note. ESM Replaying = to what extent one has replayed parts of emotional experiences in one's mind; ESM Brooding = to what extent did one think about the causes and consequences of emotional experiences; ESM Negativity = to what extent one's thoughts were negative = ESM Self-criticism = how self-critical one's thoughts were; ESM Perseveration = how much time one spends thinking about one or more emotional experiences; GAD-7 = general anxiety symptoms; BDI-II = depression symptoms; Brooding = brooding subscale of the RRS; Reflection = reflection subscale of the RRS; RRS-10 = comprises the brooding and the reflection subscales; STAI-T = trait anxiety. *$p < .05$. **$p < .01$. ***$p < .001$.

items and protocol was favorably positive (for a detailed breakdown of participants' feedback, see the supplementary materials section at https://osf.io/wj6xn). They considered that the study was not too burdensome and did not hinder their family or work life (although all but one participant were students).

Discussion

In this study, our objective was twofold: (1) to develop a low-cost and open-science ESM tool to measure rumination as a multifaceted construct over time; and (2) to evaluate the psychometric properties of this ESM tool in a community sample. Regarding our first goal, we successfully developed and tested an open-source and replicable ESM protocol, available in French and English, using *formr*. For ease of dissemination, interested researchers and practitioners can freely download the ESM protocol developed with *formr* at: https://osf.io/dngyk/. For our second goal, we recruited a community sample of forty French-speaking participants who answered the ESM survey in French four times a day over fourteen days. We found that all ESM rumination items presented high within-subject variability (i.e., all items' ICCs were lower than 0.4); it is therefore sensible to measure them frequently (Eisele et al., 2021). Correlations between the within-person means of the ESM items and the trait questionnaires of rumination, anxiety, and depression, were in the expected directions. Altogether, these results indicate that the items and the ESM tool presented here are suitable for future ESM research.

While previous studies mainly used only one or two items to measure rumination (i.e., conceptualizing it as a single construct without taking into account different key features; e.g., Faelens et al., 2021; Moberly & Watkins, 2008), the ESM items presented in this paper allow for the measurement of the five constitutive features of rumination implied by the Response Styles Theory (Nolen-Hoeksema et al., 2008). The

development of these ESM items is an important step to help usher the study of rumination from a simple, static unitary construct to a more complex and multifaceted one, embracing temporal variations and interactions of these features within and between people. In doing so, future research might better understand the onset and maintenance of rumination, possibly informing new and more effective treatments for rumination.

There are some limitations, however. First, to limit participants' burden, we only included a limited number of items by sticking to one theoretical framework: five items measuring five features of rumination, whereas many more features of repetitive thought have been studied in the literature. We did not include features such as intrusiveness and uncontrollability, nor did we include other features related to the content, such as temporal orientation or abstractedness (Wahl et al., 2019). Once additional ESM items for other rumination and repetitive thought features have been validated (see, for example, Rosenkranz et al., 2020), a critical next step could be to investigate all additional features of rumination, as depicted in other conceptualizations of rumination. Such research could likely help clarify which features are most central to understanding and intervening on rumination and repetitive thoughts. This latter point is critical since there is currently no consensus on the number of relevant dimensions of repetitive negative thinking, despite the constantly evolving nature of this field (e.g., Watkins & Roberts, 2020).

Second, we only tested the items in a community sample composed mainly of students and women. Although the results and psychometric properties are promising, future studies should evaluate the psychometric properties of these items in clinical samples. Indeed, given the transdiagnostic nature of rumination across many different disorders (Aldao et al., 2010; Cavicchioli & Maffei, 2021; Hsu et al., 2015; Smith et al., 2018; Szabo et al., 2017), it is essential to verify that the ESM items perform similarly in various clinical samples. Moreover, this study only investigated the psychometric properties of the French ESM protocol with native French-speaking participants. Therefore, further research is needed to investigate the psychometric properties of the English ESM protocol (and potentially other languages) and ensure it has similar properties. Finally, our decision to send out the ESM survey four times a day seemed to strike a balance between participants' burden (i.e., low enough according to the feedback participants gave) and within-person variability (high enough according to the ICCs). However, researchers could explore different schedules (e.g., once a day, ten times a day) in future iterations.

Aside from these limitations, the ESM tool provided has several strengths. First, the ESM rumination items provide a brief and preliminarily validated way of measuring five features of rumination. This makes it possible to combine these items with other ESM items in future studies while limiting participants' burden to a minimum. Second, in addition to testing the psychometric properties of the ESM items, this paper provides a low-cost, easily replicable, and accessible open-source ESM tool. Indeed, all the necessary resources are available on OSF (i.e., a JSON file to import the ESM protocol into *formr*, the R code to pre-process and analyze the data, and detailed instructions: https://osf.io/dngyk/). One can find detailed information about the protocol in the Supplementary Materials (available at https://osf.io/wj6xn). Lastly, this ESM tool achieved high compliance (i.e., 92%) by combining several recommendations from the ESM literature (e.g., Myin-Germeys & Kuppens, 2021) with the possibilities offered by *formr* (see supplementary materials available at https://osf.io/wj6xn).

In conclusion, rumination is a key transdiagnostic process of mental disorders. Yet, much of the literature has operationalized rumination as a unitary trait-like construct, even though most models view it as a multifaceted state-like phenomenon, thus blocking empirical progress. In this paper, we developed and validated an ESM protocol to measure, over time, five features of rumination (brooding, perseveration, negativity, self-criticism, and replaying), as implied by the seminal model of Nolen-Hoeksema (1991; Nolen-Hoeksema et al., 2008). All of our items show good psychometric properties and sufficient within-person variability while not being too burdensome for participants. Hence, we hope that this ESM tool will help researchers usher the field forward by examining how rumination and its distinct features unfold over time and dynamically interact with other psychological processes in clinical and non-clinical samples.

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