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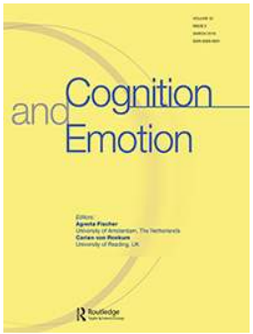

Cognition and Emotion

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/pcem20

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To cite this article: Maxime Résibois, Elise K. Kalokerinos, Gregory Verleysen, Peter Kuppens, Iven Van Mechelen, Philippe Fossati & Philippe Verduyn (2018) The relation between rumination and temporal features of emotion intensity, Cognition and Emotion, 32:2, 259-274, DOI: 10.1080/02699931.2017.1298993

To link to this article: https://doi.org/10.1080/02699931.2017.1298993

COGNITION AND EMOTION, 2018
VOL. 32, NO. 2, 259–274
https://doi.org/10.1080/02699931.2017.1298993

Routledge
Taylor & Francis Group

The relation between rumination and temporal features of emotion intensity

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ABSTRACT

Intensity profiles of emotional experience over time have been found to differ primarily in explosiveness (i.e. whether the profile has a steep vs. a gentle start) and accumulation (i.e. whether intensity increases over time vs. goes back to baseline). However, the determinants of these temporal features remain poorly understood. In two studies, we examined whether emotion regulation strategies are predictive of the degree of explosiveness and accumulation of negative emotional episodes. Participants were asked to draw profiles reflecting changes in the intensity of emotions elicited either by negative social feedback in the lab (Study 1) or by negative events in daily life (Study 2). In addition, trait (Study 1 & 2), and state (Study 2) usage of a set of emotion regulation strategies was assessed. Multilevel analyses revealed that trait rumination (especially the brooding component) was positively associated with emotion accumulation (Study 1 & 2). State rumination was also positively associated with emotion accumulation and, to a lesser extent, with emotion explosiveness (Study 2). These results provide support for emotion regulation theories, which hypothesise that rumination is a central mechanism underlying the maintenance of negative emotions.

ARTICLE HISTORY
Received 21 April 2016
Revised 10 February 2017
Accepted 15 February 2017

KEYWORDS
Emotion dynamics; intensity profiles; emotion regulation; rumination

Emotions unfold over time. Consequently, studying the dynamic nature of emotions is crucial to understanding how they operate (Davidson, 1998; Verduyn, Van Mechelen, Tuerlinckx, Meers, & Van Coillie, 2009). Studying the temporal unfolding of emotions is also of critical importance for understanding affective disorders, as disturbances in emotion dynamics are among the major criteria for the diagnosis of various mental health disorders (e.g. depression, bipolar disorder, or post-traumatic stress disorder, American Psychiatric Association, 2013).

Patterns of emotional change across time have been studied in a variety of ways. An initial approach has been to examine temporal dynamics in activity of the peripheral (Glynn, Christenfeld, & Gerin, 2002; Lapate et al., 2014; Paul, Simon, Kniesche, Kathmann, & Endrass, 2013; Siegle, Steinhauer, Carter, Ramel, & Thase, 2003) or central nervous system (Goldin et al., 2005; Grandjean & Scherer, 2008; Schuyler et al., 2014; Waugh, Hamilton, & Gotlib, 2010; Waugh, Lemus, & Gotlib, 2014; Waugh, Shing, & Avery, 2015) following exposure to emotional stimuli. An important advantage of this approach is that it allows for a rigorous examination of emotion dynamics across short timescales in controlled settings. However, it is less well suited to examine emotion dynamics across larger timescales in daily life (however, see also Wilhelm, Pfaltz, & Grossman, 2006).

A second approach has been to examine dynamics in emotional experience. For this purpose, researchers have often relied on an experience-sampling approach. The central advantages of this technique is that the data are unaffected by memory biases, and that emotion dynamics can also be assessed in daily life.

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Supplemental data for this article can be accessed here: https://doi.org/10.1080/02699931.2017.1298993

However, experience-sampling methods only provide a limited number of discrete observations. In contrast, the intensity profile approach, developed by Frijda, Mesquita, Sonnemans, and Van Goozen (1991; Sonnemans & Frijda, 1994), allows us to collect continuous data capturing the full pattern of emotion unfolding. The intensity profile approach consists of asking participants to recall a recently experienced emotional episode, and to draw a graph representing changes in the intensity of emotional experience over time.

Research on emotion intensity profiles contradicted the traditional belief that emotions have a steep onset followed by a gradual return to baseline (Frijda, 2007), demonstrating that emotion intensity profiles could instead take all sorts of shapes. To describe this profile variability, Frijda and colleagues used features such as the number of peaks and valleys, the intensity of the highest peak, and the area underneath the curve. Intensity profiles were thus a powerful tool to assess how the entire unfolding of an emotion in reaction to a particular event could be characterised by a variety of features. However, these features were selected in an *ad-hoc* manner, and it was unclear whether they were the optimal features to describe variability in intensity profiles.

More recently, Verduyn et al. (2009) empirically inferred the main features that underlie variability in emotion intensity profiles: Using functional Principal Component Analysis (PCA, Ramsay & Silverman, 2005) they found that 84% of the observed variability in profile shapes was due to differences in explosiveness (40%), accumulation (29%), and reactivation (15%). Emotion explosiveness (also referred to as reactivity) pertains to the period of emotion onset, and reflects whether the emotional profile has a steep versus a gentle start. Emotion accumulation (also referred to as skewness) pertains to the period of emotion offset, and reflects whether emotion intensity increases over time versus goes back to baseline. Finally, emotion reactivation concerns the number of peaks, that is, whether the profile contains one versus several intensity peaks. The unfolding of subjective experience is thus highly characterised by how the emotional episode starts and ends, and, to a lesser extent, by the presence or absence of several peaks of intensity.

In order to understand variability in profile shapes, one should not only examine which features optimally describe this variability, but also identify factors that influence these features (Frijda, 2007). However, there is as of yet little research on the determinants of emotion explosiveness, accumulation, and reactivation. One notable exception is a study by Verduyn, Van Mechelen, and Frederix (2012), which found that the shape of emotion intensity profiles was a function of characteristics of the emotion-experiencing person (such as personality traits) and the emotion-eliciting event (such as the importance of the event). Yet, that study did not examine the role of perhaps the primary candidate determinant of emotion unfolding: emotion regulation strategies (Gross, 2015).

Indeed, in the extended process model of emotion regulation, Gross describes emotion regulation as "the activation of a goal to influence the emotion trajectory" (Gross, 2015, p. 5). This implies that, by definition, emotion regulation should be involved in the temporal pattern of emotion intensity (Kuppens & Verduyn, 2015). Previous research has consistently found that emotion regulation strategies can impact the intensity of emotional experience (Erisman & Roemer, 2010; Gross, 2015; Hemenover, 2003; McRae, Jacobs, Ray, John, & Gross, 2012; Monfort, Stroup, & Waugh, 2015; Pe et al., 2015; Quoidbach, Mikolajczak, & Gross, 2015; Tugade & Fredrickson, 2004; Waugh, Fredrickson, & Taylor, 2008) and even the duration of an emotional response (Brans & Verduyn, 2014; Brans, Van Mechelen, Rimé, & Verduyn, 2013; Verduyn, Van Mechelen, & Tuerlinckx, 2011; Verduyn, Van Mechelen, Kross, Chezzi, & Van Bever, 2012; Waugh et al., 2016). However, these studies have yet to examine how regulation strategies influenced the pattern of emotion unfolding as reflected in emotion explosiveness, accumulation, and reactivation. One notable exception was research that examined the relationship between emotion regulation strategies and the shape of emotion intensity profiles (Heylen, Verduyn, Van Mechelen, & Ceulemans, 2015). However, their method (i.e. clustering emotional episodes according to their overall profile shape) did not allow pinpointing which specific features of emotion intensity profiles (i.e. explosiveness, accumulation, or reactivation) were influenced by the use of emotion regulation strategies, which is of key importance for understanding how such strategies may differentially influence the diverse processes associated with emotion unfolding. The overall aim of the present research is to examine the relation between emotion regulation strategies and specific intensity profile features.

Study 1

The aim of the first study is to examine the relationship between dispositional emotion regulation and

temporal features of negative emotion intensity profiles. A large number of regulation strategies have been distinguished, with some of these strategies being generally effective in decreasing the intensity of negative emotional experience (Garnefski, Kraaij, & Spinhoven, 2001) and others tending to strengthen negative emotional experiences. It should be noted that, even though decreasing negative emotion intensity is the most frequent motivation underlying emotion regulation (Riediger, Schmiedek, Wagner, & Lindenberger, 2009), other motivations may also play a role. Indeed, it has been shown that one might up-regulate negative emotions in order to achieve a higher-order goal or for potential long-term benefits (Tamir, 2016), such as when up-regulating anger in a confrontational situation (Tamir, 2009).

In their framework of cognitive emotion regulation, Garnefski et al. (2001) differentiate between four strategies to up-regulate negative emotions (rumination, self-blaming, blaming others, and catastrophising) and five strategies to down-regulate negative emotions (positive reappraisal, acceptance, refocus on dealing with the situation, positive refocusing, and putting the event into perspective). As emotion regulation is theorised to influence primarily the period of emotion offset, rather than the period of emotion onset (Koole, 2009), we expect that dispositional tendencies to use each of these strategies would be primarily related to emotion accumulation and reactivation (rather than emotion explosiveness). More specifically, consistent with previous studies on the relation between these cognitive emotion regulation strategies and the experiential and physiological components of emotional responses (Garnefski et al., 2001; Gerin, Davidson, Christenfeld, Goyal, & Schwartz, 2006; Key, Campbell, Bacon, & Gerin, 2008; Martin & Dahlen, 2005; Mauss, Levenson, McCarter, Wilhelm, & Gross, 2005; Thiruchselvam, Blechert, Sheppes, Rydstrom, & Gross, 2011), we expect the up-regulation strategies to be positively related to emotion accumulation and reactivation. In contrast, we expect the down-regulation strategies to be negatively related to emotion accumulation and reactivation.

To test these hypotheses, we made use of a social feedback paradigm (Bushman & Baumeister, 1998; Eisenberger, Inagaki, Muscatell, Byrne Haltom, & Leary, 2011; Nummenmaa & Niemi, 2004; Somerville, Heatherton, & Kelley, 2006). This paradigm consists of exposing participants to negative social feedback on a task performed earlier and assessing their subsequent emotional response. It has been shown that such feedback typically elicits enduring emotional responses (Wager et al., 2009) and, hence, this task is ideally suited to examine emotion dynamics.

More specifically, participants were first asked to write short essays on topics reflecting their dreams and desires. Second, while judges were supposedly trying to infer their personality from these texts, we measured participants' dispositional tendencies to use a set of emotion regulation strategies[1] including the cognitive strategies distinguished in the theoretical framework of Garnefski (Garnefski et al., 2001). As rumination is considered to consist of several subtypes (Raes et al., 2009; Treynor, Gonzalez, & Nolen-Hoeksema, 2003), we measured separately the dispositional tendencies to brood and to reflect on negative experiences. Finally, as Garnefski's framework only contains *cognitive* strategies that may occur *following* negative events, we also measured the degree to which participants tend to suppress their emotions (Goldin, McRae, Ramel, & Gross, 2008), and to worry (Watkins, 2008), in order to explore the role of *behavioural* regulation strategies, and *future-oriented* cognitive strategies, respectively. As these two strategies are known to strengthen negative emotions (Brans, Koval, Verduyn, Lim, & Kuppens, 2013; Gross, 2015; Watkins, 2008), they are expected to be positively related to emotion accumulation and reactivation. Third, following the completion of these emotion regulation questionnaires, participants received negative and neutral feedback (personality assessments), independent of the content of the essays they wrote. After each piece of feedback, participants were asked to report on changes in the intensity of their feelings that occurred while reading and thinking about the feedback.

Method

In the sections below, we report how we determined our sample size, all data exclusions, all manipulations, and all measures in the study.

Participants

Participants were 45 native Dutch speakers (31 females and 14 males) recruited in Leuven (Belgium) through flyers posted around KU Leuven campus and by posting the study on a digital platform that is read by university students who are interested in research participation. Their mean age was 22.13

years (SD = 2.13). The number of participants was based on an earlier multilevel study on the link between regulation strategies and emotions, where 46 participants were shown to be sufficient to detect meaningful effects (Brans, Koval, et al., 2013). Four participants were removed from the sample as they expressed some suspicion regarding the existence of the essay evaluators during funnelled debriefing.[2] As such, the final sample consisted of 41 participants (29 females and 12 males) with a mean age of 21.97 years (SD = 1.96). The study was approved by the social and societal ethics committee and the medical ethics committee of KU Leuven. Participants provided written informed consent prior to the start of the study and received 15 Euros as compensation for their participation.

Materials

Cognitive emotion regulation questionnaire. We measured participants' dispositional tendency to use cognitive emotion regulation by means of Garnefski and colleagues' Cognitive emotion regulation questionnaire (CERQ, 2001), which consists of 36 items rated using a 5-point Likert scale, ranging from 1 (*almost never*) to 5 (*almost always*). Items are divided in nine scales, with each scale assessing the dispositional use of a particular cognitive emotion regulation strategy when facing negative events: Self-blame (e.g. "I think about the mistakes I have made in this matter", $\alpha = .82$), blaming others (e.g. "I feel that others are responsible for what has happened", $\alpha = .94$), acceptance (e.g. "I think that I cannot change anything about it", $\alpha = .79$), refocus on planning (e.g. "I think about how I can best cope with the situation", $\alpha = .87$), positive refocusing (e.g. "I think of nicer things than what I have experienced", $\alpha = .83$), rumination (e.g. "I often think about how I feel about what I have experienced", $\alpha = .89$), positive reappraisal (e.g. "I think that I can become a stronger person as a result of what has happened", $\alpha = .81$), putting into perspective (e.g. "I tell myself that there are worse things in life", $\alpha = .89$), and catastrophising (e.g. "I often think that what I have experienced is much worse than what others have experienced", $\alpha = .75$).

Ruminative response scale. To further explore brooding and reflection subtypes of rumination, we used the Dutch version (Raes et al., 2009) of the RSS recommended by Treynor et al. (2003), which includes 5 items to measure brooding (e.g. "I think 'Why do I have problems other people don't have?'", $\alpha = .72$) and 5 items to measure reflection (e.g. "I write down what I am thinking and analyse it", $\alpha = .75$). Items were rated using a 4-point Likert scale, ranging from 1 (*almost never*) to 4 (*almost always*).

Emotion regulation questionnaire. In order to measure dispositional tendencies to use a behavioural regulation strategy, we used a Dutch translation of Gross and John' Emotion regulation questionnaire (ERQ, Gross & John, 2003), which consists of 10 items rated using a 7-point Likert scale, ranging from 1 (*strongly disagree*) to 7 (*strongly agree*). Items are divided into two scales: Suppression (e.g. "I keep my emotions to myself", $\alpha = .80$) and reappraisal (e.g. "I control my emotions by changing the way I think about the situation I'm in", $\alpha = .84$).

Penn state worry questionnaire. Finally, to measure the importance of repetitive thoughts oriented towards future potential negative outcomes, we included a Dutch translation of Meyer and colleagues' Penn State Worry Questionnaire (PSWQ, Meyer, Miller, Metzger, & Borkovec, 1990), which consists of 16 items rated using a 5-point Likert scale, ranging from 1 (*not at all typical of me*) to 5 (*very typical of me*). All items belong to one scale reflecting the disposition to worry (e.g. "I worry about projects until they are all done", $\alpha = .95$).

Social feedback: personality assessments. Following the CERQ, participants were exposed to manipulated negative and neutral feedback. The feedback was modelled after earlier studies using social feedback to induce emotions (Bushman & Baumeister, 1998; Eisenberger et al., 2011; Harmon-Jones & Sigelman, 2001). In particular, the first feedback screen consisted of ratings on desirable (social, interesting, and honest) and undesirable (stubborn, superficial, and naïve) personality traits. The second feedback screen contained a rating reflecting the desire of the essay evaluator to have the participant as a friend. Negative feedback consisted of low scores on desirable traits, high scores on undesirable traits, and a low score on the item reflecting judge's desire to be friends. Neutral feedback consisted of ratings close to the neutral scale midpoint of all feedback items. Independent of the content of their essays, participants were exposed to eight pieces of negative feedback and four pieces of neutral feedback. Feedback was

presented in one of two pre-specified orders with a maximum of two negative trials following each other.

Procedure

The experiment consisted of four phases. During Phase 1 (lasting for about 25 min), participants were asked to write four short texts on pre-specified topics reflecting their dreams and ambitions (e.g. "Write a short text about what you would like to change about the world"). They were then led to believe that these essays would be read by three judges, who would independently try to estimate participants' personality from the essays. It was further explained to participants that the (supposed) judges would be deceived in thinking that each text was written by someone else, which would (supposedly) allow the experimenters to study the stability of judges' first impressions.

During Phase 2 (lasting for about 25 min), participants completed the CERQ, the Ruminative Response Scale (RRS), the ERQ, and the PSWQ, while the judges were supposedly reading their texts and estimating their personality. For exploratory purposes, participants were also asked to complete a number of questionnaires assessing personality and well-being that are not relevant to the current research question, and so will not be further discussed.[3]

During Phase 3 (lasting for about 45 min), participants were shown feedback on their texts across twelve consecutive trials, and were asked to read and think about this feedback. To strengthen the cover story, they were first asked to rate the degree to which they thought the feedback was accurate, and to guess which was the text used by the judge for the personality assessment displayed. Participants then indicated whether they experienced the feedback as positive, negative, or neutral and, when applicable, specified the nature of the positive (joy, gratitude, pride, or other positive emotion) or negative (sadness, anger, shame, or other negative emotion) emotion they felt. In addition, participants were asked to report on changes in the intensity of the emotion they experienced while reading and thinking about the feedback by drawing an emotion intensity profile using a computer mouse. For this purpose, a two-dimensional grid was presented. The *X*-axis coordinates, representing time, were stored with a resolution of 780 pixels and were divided into two main parts. The first part occupied a quarter of the screen and corresponded to the 30-second period during which participants read the feedback. The second part occupied three quarters of the screen and corresponded to the 90-second period during which they thought about the feedback. The *Y*-axis coordinates, representing the intensity of the experienced emotion, were stored with a resolution of 510 pixels and were divided into seven intervals ranging from "no emotion" to "very high". Finally, each trial ended with a 15-second relaxation period (see Figure 1 for a visual representation of the structure of the trials).

During Phase 4 (lasting for about 10 min), a funnelled debriefing procedure was adopted to measure possible suspicion about the existence of the judges. Finally, a full debriefing followed including an explanation of the real purpose of the study.

Data analysis

Intensity profile features

Emotion intensity profiles entered the analysis when the feedback was (a) designed to induce a negative emotion[4] and (b) experienced as negative. This resulted in a dataset containing 293 emotion intensity profiles. Similar to the procedure employed by Verduyn, Van Mechelen, and Frederix (2012; Verduyn et al., 2009), all intensity profile time points were transformed into a function by means of linear interpolation – as implemented in Matlab R2015b's interp1 function (v. 8.6.0.267246 - R2015b; The MathWorks Inc., 2015) – and, subsequently, discretised into 150 equally distanced time points. All resulting discretised intensity profile time series were then decomposed using PCA on the covariance matrix with a VARIMAX rotation – as implemented in SPSS (v. 23; IBM Corp, 2015) – to ease substantive interpretation of the component solution. PCA decomposes intensity profiles into component loadings and component scores. The component loadings represent the shape of component profiles over time and correspond to the dynamic features underlying profile variability. The component scores can be considered as weights that reflect the degree to which each intensity profile is characterised by each of the features. Taken all this together, each intensity profile is reconstructed as a weighted sum of dynamic features.

Relationship between dispositional emotion regulation and profile features

To assess the relationship between the dispositional tendencies to use the different emotion regulation strategies and the shape of emotion intensity profiles, the component scores obtained from the PCA solution

Prepare	Fb1	Fb2	Think	Rate1	Rate2	Rate3	Relax
7s	23s	7s	90s	sp	sp	sp	15s

Figure 1. Time course of one trial (in seconds). Each trial started with a screen notifying the participant that feedback was about to be shown. Subsequently, negative (8 trials) or neutral (4 trials) feedback was presented: the first feedback screen contained ratings on personality traits (Fb1) and the second feedback screen reflected the desire of the judge to have someone like the participants as a friend (Fb2). Next, participants were asked to think about the feedback for 90 seconds. Subsequently, they were asked to rate the accuracy of the feedback, to guess which of their texts the feedback was based upon (Rate 1), and to indicate the valence and discrete nature of the emotion elicited by the feedback (Rate 2). When a positive or negative emotion was experienced, participants were asked to draw a profile reflecting changes in the intensity of the emotion that occurred while reading and thinking about the feedback (Rate 3). Finally, participants were asked to relax before a new trial started. sp = self-paced.

were regressed on the measured regulation strategies in a series of multilevel analyses using the lme function from the nlme (v. 3.1–124; Pinheiro, Bates, DebRoy, Sarkar, & R Core Team, 2016) package developed for R (v. 3.2.3; R Core Team, 2015). This data-analytic strategy accounts for the nested data structure (trials nested within participants). Component scores were predicted by an intercept at Level 1 of the model (the intercept was allowed to vary randomly across participants) and by the dispositional tendencies to use the different regulation strategies, centred at the grand-mean, at Level 2.

Results

Manipulation check

Negative feedback was found to elicit negative emotions more often compared to neutral feedback, $z(492) = 10.62$, $p < .0001$. In particular, negative feedback was typically experienced as negative (89.3%), and only in a minority of cases as neutral (10.4%) or positive (0.3%). The negative feelings experienced were anger in 47.4% of cases, sadness in 16.2% of cases, shame in 13.0% of cases, and another non-specified negative emotion in 23.4% of cases. In contrast, neutral feedback was typically experienced as neutral (73.2%) and only in a minority of cases as negative (9.1%) or positive (17.7%). Finally, as an aside, it is interesting to note that negative feedback ($M = 2.31$, SD = 1.10) was judged to be less accurate than neutral feedback ($M = 3.71$, SD = 1.10), $t(450) = -21.07$, $p < .0001$.

Emotion intensity profile features

The emotion intensity profiles were decomposed using PCA. In line with earlier studies (Verduyn et al., 2009; Verduyn, Van Mechelen, & Frederix, 2012), the appropriate number of components was decided by means of a scree plot (see Figure S2, panel A). Using the elbow-criterion, a two-component solution was retained. These two components explained 92.7% of the variance, with, after VARIMAX rotation, the first and second components explaining 59.9% and 32.8% of the variance, respectively. Similar to Verduyn, Van Mechelen, and Frederix (2012; Verduyn et al., 2009), to interpret the component solution, we created reconstructed intensity profiles scoring high (90th percentile), average, or low (10th percentile) on one component while taking an average score on the other component. These reconstructed profiles are depicted in Figure 2 with components presented according to the order of their peaks in the temporal process.

The first component reflects emotion explosiveness, as differences between the reconstructed profiles mainly pertain to the period of emotion onset, with the high- and low-scoring profiles showing an explosive and gentle start, respectively. The second component represents emotion accumulation, as differences between the reconstructed profiles mainly pertain to the period of emotion offset, with high- and low-scoring profiles reflecting emotion intensification and recovery, respectively. In sum, the two main features underlying variability in negative emotion intensity profiles in the current data are emotion explosiveness and emotion accumulation.

Determinants of intensity profile features

The results of simple multilevel analyses regressing emotion explosiveness and accumulation on each of the regulation strategies separately are presented in Table 1 (without correction for multiple testing; underneath the table, we also note the critical Bonferroni-corrected alpha value). As expected, no significant relationships were found for emotion explosiveness (all $ps > .11$). In contrast, emotion accumulation was related to two scales of the CERQ: *positive refocusing* was marginally significantly and negatively associated with emotion accumulation, whereas *rumination* was significantly and positively associated with emotion

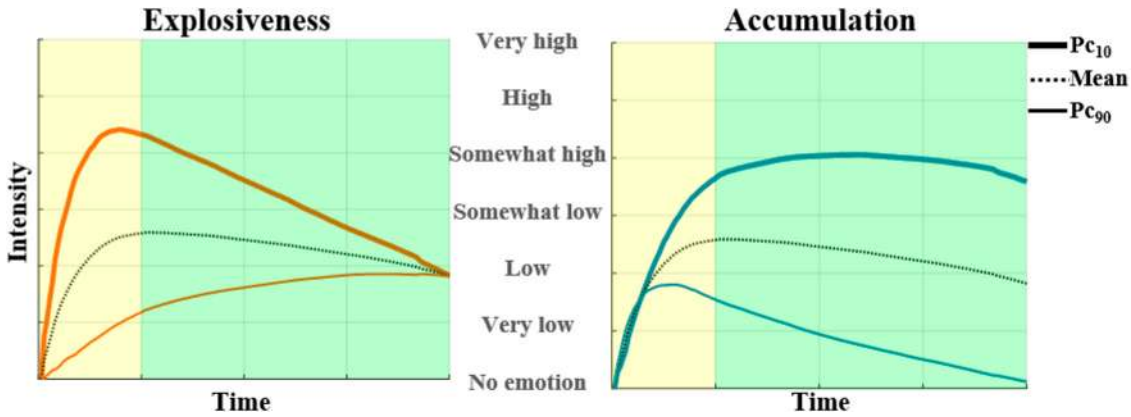

Figure 2. Reconstructed profiles (Study 1). Reconstructed profiles taking a high (90th percentile), average, or low (10th percentile) score on the component of interest and an average score on the other component. Yellow (left) and green (right) backgrounds correspond to the periods when reading, and thinking about the feedback, respectively. Left panel: High- and low-scoring profiles show an explosive and gentle start, respectively (explaining 32.8% of profile variability). Right panel: High- and low-scoring profiles show emotion intensification and recovery, respectively (explaining 59.9% of profile variability).

accumulation.[5] Moreover, when adding the two simultaneously as predictors of accumulation, both *rumination* ($B = .21$, $\beta = .57$, $t(38) = 1.88$, $p = .07$) and *positive refocusing* ($B = -.24$, $\beta = -.52$, $t(38) = -1.69$, $p = .099$) were found to have a marginally significant unique predictive contribution. In addition, we examined the relationship between rumination and accumulation in more detail using the RRS subscales. Simple multilevel analyses revealed that only the *brooding* subscale, but not the *reflection* subscale, was positively and significantly related to emotion accumulation. Finally, the behavioural regulation strategy under study (i.e. suppression), and future-oriented strategy (i.e. worry) were not related to emotion accumulation (all *p*s > .70).

Discussion

Replicating earlier findings (Verduyn et al., 2009; Verduyn, Van Mechelen, & Frederix, 2012), emotion explosiveness and accumulation were found to be the two main features underlying differences in the shape of emotion intensity profiles. This provides support to theoretical frameworks in the field of emotion dynamics (Brans & Verduyn, 2014; Davidson, 1998; Koole, 2009) according to which emotion onset and offset are governed by distinctive underlying processes such that episodes may differ in explosiveness, accumulation, or both.

In contrast to earlier studies on emotion intensity profiles (Verduyn et al., 2009; Verduyn, Van Mechelen, & Frederix, 2012), emotion reactivation was not found to underlie variability in profile shapes. This might be due to contextual factors, as the present study took place in the controlled environment of the lab, whereas in earlier studies emotion dynamics were assessed in daily life. One might conjecture that reactivations were not likely to occur in the present laboratory context as the experimental design did not leave room for reappearances of the emotion-eliciting event, which has been shown to be a central determinant of emotion reactivation (Verduyn, Van Mechelen, & Frederix, 2012).

Importantly, in the present study we found evidence for a relationship between patterns of emotion unfolding and habitual use of emotion regulation strategies. As expected, emotion regulation strategies were linked with the offset rather than the onset phase of emotion unfolding. Regarding the up-regulation strategies under study, rumination (especially the component brooding) was positively related to accumulation. This finding is consistent with earlier work on rumination illustrating the negative consequences of this regulation strategy for emotional recovery (Bushman, 2002; McLaughlin, Borkovec, & Sibrava, 2007; Nolen-Hoeksema & Morrow, 1991; Rude, Little Maestas, & Neff, 2007), and extends this work by identifying the role of rumination during the process of emotion unfolding. The relationships with the down-regulation strategies were less clear-cut, although it should be noted that positive refocusing was negatively associated with accumulation, albeit only marginally.

Although the present study yields some interesting results, it also gives rise to four new questions. First, the study was exploratory in nature. This was an

Table 1. Regression weights of dispositional emotion regulation predicting emotion explosiveness and accumulation in simple multilevel analyses (i.e. Regulation strategies were entered separately).

	Explosiveness				Accumulation			
	B	*β*	*t*	*p*	*B*	*β*	*t*	*p*
CERQ								
Self-blame	−.02	−.04	−.11	.92	.20	.42	1.27	.21
Blaming others	.13	.36	.96	.34	.03	.06	.19	.85
Acceptance	−.01	−.02	−.06	.95	.12	.27	.83	.41
Refocusing on planning	−.04	−.10	−.27	.79	.06	.14	.42	.67
Positive refocusing	−.04	−.09	−.24	.81	−.28	−.60	−1.91	.06(*)
Rumination	.09	.28	.75	.46	.24	.64	2.09	.04*
Positive reappraisal	.14	.39	1.04	.31	−.16	−.38	−1.17	.25
Perspective taking	−.07	−.20	−.53	.60	−.12	−.32	−.96	.34
Catastrophising	.04	.09	.24	.81	.26	.53	1.67	.10
RRS								
Brooding	−.15	−.31	−.82	.42	.43	.75	2.44	.02*
Reflection	−.02	−.04	−.11	.92	.19	.34	1.06	.29
ERQ								
Suppression	−.16	−.58	−1.57	.12	.01	.05	.15	.88
Reappraisal	.12	.38	1.00	.33	−.04	−.12	−.38	.71
PSWQ	−.14	−.38	−1.00	.32	.01	.03	.10	.92

Notes: *β* is the within-person standardised *B* value computed following the recommendation of Schuurman, Ferrer, de Boer-Sonnenschein, and Hamaker (2016), and is added as a measure of effect size. For results to be significant when correcting for multiple testing (using a Bonferroni correction), the *p*-value should be lower than .004.

(*)$p < .10$.

*$p < .05$.

inevitable consequence of a lack of earlier studies that could inform us which strategies were most likely to be related to the main dynamic features of emotion intensity. As a result, we needed to include many ERQs. Thus, we conducted many tests of significance, and this multiple testing could lead to an increased Type I error rate. To deal with this issue, one might correct for multiple testing. However, in cases like this, such a correction is a fairly conservative approach. This is illustrated by the fact that, after correction, no single regulation strategy (including rumination) was still significantly related to accumulation. Instead, we decided to take a less conservative, but more meaningful approach, by examining whether significant results (before correction) could be replicated in a follow-up study. Second, despite that we based our sample on a previous experience-sampling study (Brans, Koval, et al., 2013), a post-hoc power analysis suggested that a larger sample size would be preferable.[6] Third, one may wonder whether the present findings would still hold when examining emotion dynamics in daily life rather than in a controlled laboratory environment. Fourth, while the current findings tell us that people who ruminate more tend to have negative emotional episodes higher in accumulation, this does not necessarily imply that higher rumination is involved in episodes characterised by higher accumulation (Zuckerman, 1983). In other words, it remains to be seen whether rumination is also related to emotion accumulation at the state level.

Study 2

The first aim of the second study is to replicate the finding of Study 1 that trait rumination (especially the component brooding) is positively associated with emotion accumulation but now when assessing emotion dynamics in daily life and using a larger sample. Therefore, intensity profiles of negative emotions were collected within a daily diary paradigm (Verduyn, Van Mechelen, & Frederix, 2012), which allows us to study emotion dynamics while limiting memory biases (Bolger, Davis, & Rafaeli, 2003).

Second, we examined the relationship between state measures of emotion regulation and temporal features of emotion intensity. Again, we measured a set of cognitive and behavioural emotion regulation strategies. For pragmatic reasons, we limited ourselves to the study of five regulation strategies selected from Gross' model of emotion regulation, which distinguishes between situation selection, attentional deployment (encompassing distraction and rumination), reappraisal, and suppression (Gross, 1998; Webb, Miles, & Sheeran, 2012). To enhance the comparability of the affective correlates of trait and state regulation, we also assessed the

mentioned strategies at the dispositional level. In line with results obtained in Study 1, we hypothesise that situation modification, distraction, and reappraisal (generally perceived as strategies that down-regulate negative emotions) are negatively related to accumulation whereas the opposite holds for rumination and suppression (generally perceived as strategies that up-regulate negative emotions).

Method

In the sections below, we report how we determined our sample size, all data exclusions, all manipulations, and all measures in the study.

Participants

Participants were 74 Americans (33 females and 41 males; 61 European-Americans, 6 Latino Americans, 4 Asian Americans, 1 African American, 1 European-Asian American, and 1 European-Latino American), recruited through Amazon's Mechanical Turk, who completed 480 daily diaries. These participants were a subsample of a larger group of participants ($N = 114$)[7] recruited for a larger study, and were selected for this study because their browser had the technical capability to draw their intensity profile. Given that some findings were marginally significant in Study 1, we made use of a larger sample size in Study 2. Specifically, a formal power analysis recommends a sample of 80 to detect small to medium effect sizes ($r = .30$, alpha = .05, power = .80). There were no significant differences between this subsample and the larger group on demographic variables, Big Five Inventory (John, Naumann, & Soto, 2008) personality traits, depressive symptoms as measured by the Center for Epidemiologic Studies Depression Scale (Radloff, 1977), or emotion regulation dispositions. Their mean age was 36.93 years (SD = 12.35). Participants were paid up to $USD12.60.[8]

Materials

These data were acquired as part of a larger project (see, e.g. Kalokerinos, Résibois, Verduyn, & Kuppens, 2016). Below we present only materials that are relevant to the current research questions.[9]

Treynor's RRS. In line with Study 1, participants completed the RRS recommended by Treynor and colleagues (Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008; Treynor et al., 2003), which includes five items measuring brooding ($\alpha = .87$) and five items measuring reflection ($\alpha = .80$).

Gross' emotion regulation strategies. Participants reported on their habitual use of emotion regulation strategies using a 7-point Likert scale ranging from 1 (*I did not do this at all*) to 7 (*I did this very much*). Items appeared in a randomised order and assessed participants' habitual use (*How much do you usually use each of the following strategies to influence your emotion?)* of situation modification (*I took steps to change the situation*), distraction (*I distracted myself from the event or my emotions*), rumination (*I ruminated or dwelled on the event or my emotions*), reappraisal (*I changed my perspective or the way I was thinking about the event*), and suppression (*I suppressed the outward expression of my emotions*).

Daily questionnaires. Participants were first asked to describe briefly the most negative event they experienced that day. Next, participants reported on state regulation by indicating the degree to which they used five regulation strategies in response to that event using the items described above: Situation modification, distraction, rumination, reappraisal, and suppression. Subsequently, participants were asked to report the duration of the emotion they felt in response to the negative event (in hours, minutes, and/or seconds), and to draw a profile that reflected how the intensity of the negative emotion they experienced changed during the emotional episode using a similar approach as in Study 1.

Procedure

Participants first completed questionnaires assessing their dispositional tendency to use a set of regulation strategies: Situation modification, distraction, rumination (brooding and reflection), reappraisal, and suppression. Next, participants completed daily diaries for a period of seven days. More specifically, each day at 7 PM, participants received an email containing a link to the daily questionnaires and were asked to respond to the questions posed.

Data analysis

Intensity profile features

The final dataset consisted of 480 emotion intensity profiles. To avoid differences in duration, rather than differences in shape, driving the results, duration differences were controlled for by stretching all

profiles to equal length (Heylen et al., 2015; Heylen, Ceulemans, Van Mechelen, & Verduyn, 2016; Verduyn et al., 2009; Verduyn, Van Mechelen, & Frederix, 2012). This ensured that differences in explosiveness and accumulation pertain to shape differences rather than duration differences. Indeed, profiles may differ in duration while having a similar degree of explosiveness and accumulation. For example, waiting for a medical test result for days or preparing for a public lecture the next day may be accompanied by a similar high degree of accumulation (and low degree of explosiveness) while the duration of the episodes strongly differ. Alternatively, the unexpected occurrence of a threatening image during a horror movie is likely to be followed by an emotional response high in explosiveness (and low in accumulation), whereas a signal that a threatening image may occur is likely to be followed by a response high in accumulation (and low in explosiveness), despite that the duration of both episodes is similarly short.[10]

Following the stretching preprocessing step, intensity profile time points were subsequently interpolated and discretised into 150 equally distanced time points, consistent with the procedure employed in Study 1. The resulting discretised intensity profiles were then again decomposed using PCA on time series with a VARIMAX rotation.

Relationship between emotion regulation and profile features

Dispositional emotion regulation. As in Study 1, the relationship between dispositional tendencies to use emotion regulation strategies and the shape of emotion intensity profiles was assessed by regressing the component scores obtained from the PCA solution on the measured regulation strategies in a series of multilevel analyses. In particular, component scores were predicted at Level 1 of the model by an intercept (which was allowed to vary randomly across participants) and by the dispositional tendencies to use regulation strategies, centred at the grand-mean, at Level 2 of the model.

State emotion regulation. The relationship between the state measures of emotion regulation strategies and the shape of emotion intensity profiles was assessed by regressing the component scores obtained from the PCA solution on the measured regulation strategies in a series of multilevel analyses. In particular, at Level 1 of the model component scores were predicted by state measures of regulation strategies centred at the group-mean. Intercept and slopes were allowed to vary randomly across participants.

Results

Emotion intensity profile features

Again, the elbow-criterion of the scree plot (see Figure S2, panel B) suggested a two-component solution. These two rotated components explained 86.4% of the variance, with the first and second components explaining 51.4% and 35.1% of the variance, respectively. As in Study 1 we created reconstructed intensity profiles scoring high (90th percentile), average, or low (10th percentile) on one component while taking an average score on the other component. These reconstructed profiles are depicted in Figure 3 with components presented according to the order of their peaks in the temporal process.

The first component reflects emotion explosiveness, as differences between the reconstructed profiles mainly pertain to the period of emotion onset, with the high- and low-scoring profiles showing an explosive and gentle start, respectively. The second component represents emotion accumulation, as differences between the reconstructed profiles mainly pertain to the period of emotion offset, with high- and low-scoring profiles reflecting emotion intensification and recovery, respectively. In sum, the two main features underlying variability in negative emotion intensity profiles in the present study are again emotion explosiveness and emotion accumulation.

Determinants of intensity profile features

Trait emotion regulation. The results of simple multilevel analyses regressing emotion explosiveness and accumulation on each of the dispositional regulation strategies separately are presented in Table 2. As expected, no significant relationships were found for emotion explosiveness (all $ps > .35$). In contrast, emotion accumulation was positively related to the habitual use of *rumination* and especially the *brooding* component.

State emotion regulation. The results of simple multilevel analyses regressing emotion explosiveness and accumulation on each of the state regulation strategies separately are presented in Table 3.[11] State *rumination* was positively related to emotion accumulation

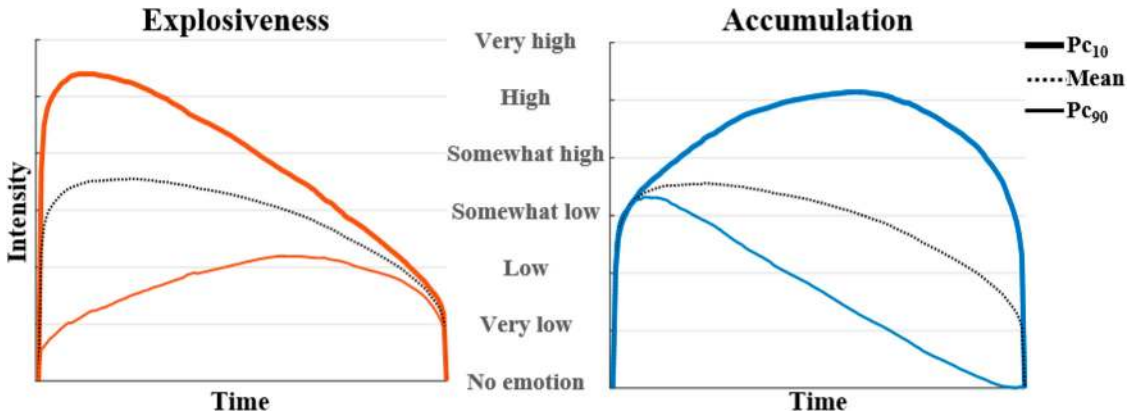

Figure 3. Reconstructed profiles (Study 2). Reconstructed profiles taking a high (90th percentile), average, or low (10th percentile) score on the component of interest and an average score on the other component. Left panel: High- and low-scoring profiles show an explosive and gentle start, respectively (explaining 35.1% of profile variability). Right panel: High- and low-scoring profiles show emotion intensification and recovery, respectively (explaining 51.4% of profile variability).

and, surprisingly, also to emotion explosiveness albeit to a lesser extent. Moreover, when entering all variables as predictors of explosiveness that turned out to have (marginally) significant weights in the simple analyses, both *rumination* ($B = .08$, $\beta = .20$, $t(403) = 3.34$, $p < .001$) and *distraction* ($B = .06$, $\beta = .14$, $t(403) = 2.42$, $p = .02$), but not *suppression* ($B = .03$, $\beta = .08$, $t(403) = 1.10$, $p = .27$), were found to have a significant unique predictive contribution.

Discussion

In line with Study 1 and earlier studies on emotion intensity profiles (Verduyn et al., 2009; Verduyn, Van Mechelen, & Frederix, 2012), emotion explosiveness and accumulation were found to be the two main features underlying differences in the shape of emotion intensity profiles. Surprisingly, however, emotion reactivation was not found to be a key feature, despite the fact that in the present study emotion dynamics were assessed in daily life. However, it should be noted that emotion reactivation accounted for a relatively small percentage of profile variability in previous research on this topic, which lowers the probability of a successful replication. Future studies are needed to examine whether emotion reactivation is a core feature of variability in emotion unfolding.

Trait rumination, and especially the brooding component, was found to be positively related to emotion accumulation. As in Study 1, this relationship becomes non-significant when correcting for multiple testing. However, the fact that this finding replicates in both studies reflects the robustness of this relationship. Extending these results, *state* rumination was also

Table 2. Regression weights of trait ERQs predicting emotion explosiveness and accumulation in simple multilevel analyses (i.e. Regulation strategies were entered separately).

	Explosiveness				Accumulation			
	B	*β*	*t*	*p*	*B*	*β*	*t*	*p*
RRS								
Brooding	−.03	−.04	−.27	.79	.23	.37	2.23	.03*
Reflection	.03	.03	.22	.83	.06	.08	.49	.63
Habitual use of …								
… Situation modification	.05	.13	.92	.36	.08	.26	1.59	.12
… Distraction	−.01	−.04	−.28	.78	.00	.01	.07	.95
… Rumination	.01	.02	.13	.90	.08	.32	1.98	.05(*)
… Reappraisal	.02	.06	.40	.69	−.04	−.13	−.78	.44
… Suppression	.00	.00	.001	1.00	.01	.03	.15	.88

Notes: *β* is the within-person standardised *B* value computed following the recommendation of Schuurman et al. (2016), and is added as a measure of effect size. For results to be significant when correcting for multiple testing (using a Bonferroni correction), the *p*-value should be lower than .007.
(*)$p < .10$.
*$p < .05$.

Table 3. Regression weights of state ERQs predicting emotion explosiveness and accumulation in simple multilevel analyses (i.e. Regulation strategies were entered separately).

	Explosiveness				Accumulation			
	B	*β*	*t*	*p*	*B*	*β*	*t*	*p*
State use of …								
… Situation modification	−.02	−.06	−.89	.37	.01	.09	.44	.66
… Distraction	.06	.17	2.81	.01*	−.03	−.10	−1.07	.29
… Rumination	.08	.21	3.32	.001*	.12	.26	4.02	<.001*
… Reappraisal	−.03	−.09	−1.34	.18	−.02	−.08	−.86	.39
… Suppression	.04	.13	1.91	.06*	.01	.03	.39	.70

Notes: *β* is the within-person standardised *B* value computed following the recommendation of Schuurman et al. (2016), and is added as a measure of effect size. For results to be significant when correcting for multiple testing (using a Bonferroni correction), the *p*-value should be lower than .01.
*$p < .10$.

positively linked with emotion accumulation. Moreover, state (but not trait) rumination was also related to emotion explosiveness and the relationships between state rumination and emotion dynamics held after correcting for multiple testing. Therefore, taken together, the overall pattern of results implies fairly consistent associations between rumination and patterns of emotion unfolding. Finally, it is notable that emotion explosiveness was also positively related to state distraction.

General discussion

The main aim of the present studies was to examine the relationship between emotion regulation and temporal features of emotion intensity. Among the regulation strategies examined, rumination was found in both studies to be the strongest predictor of emotion unfolding. Both trait and state rumination were associated with emotion accumulation regardless whether the emotion occurred in a controlled social context (Study 1), or in daily life where emotions follow both social and non-social events (Study 2). Rumination entails repetitively thinking about one's negative emotions (Treynor et al., 2003) and the present findings suggest that this process intensifies emotions as time progresses. This period of emotion accumulation may, in turn, even result in a deterioration of well-being and physical health as suggested by other research (Bushman, 2002; McLaughlin et al., 2007; Nolen-Hoeksema & Morrow, 1991; Rude et al., 2007). This potential temporal cycle of rumination will be an important topic for future research.

In contrast to trait rumination, which was unrelated to emotion explosiveness, state rumination was also related to emotion explosiveness. However, this does not necessarily imply that rumination increases the explosiveness of emotional responses. The relationship between state emotion regulation and emotion intensity is likely to be reciprocal (Brans & Verduyn, 2014; Sonnemans & Frijda, 1995), such that explosive episodes may lead to excessive use of rumination, which may in turn lead to emotion accumulation. A similar explanation may account for the observed positive relationship between distraction and emotion explosiveness, such that people are more likely to distract themselves when initial emotional intensity is high. In fact, it has recently been shown that distraction is especially often used when emotion intensity is high (Gross, 2015; Sheppes et al., 2014). Future experimental studies are needed to further disentangle cause and effect in the complex relationship between emotion regulation and emotion dynamics.

The only emotion regulation strategy that was found to be predictive of emotional recovery was positive refocusing in Study 1, albeit this result was only marginal. This finding is nevertheless consistent with earlier work showing that mentally disengaging from negative emotions and refocusing on positive distractors is an effective method to shut down an emotional response (Verduyn et al., 2011), at least in the short term (Garnefski et al., 2001). It should be noted, however, that this strategy is not readily available for everyone. For example, it has been shown that people suffering from depression have difficulty implementing this strategy (Wenzlaff, Wegner, & Roper, 1988).

As the study of determinants of emotion intensity profile features is still in its early stages, several challenges remain for future research. The present findings only pertain to the temporal unfolding of negative emotions. A growing literature has developed showing that people dampen or savour their positive emotions using a wide range of regulation strategies as well (Quoidbach, Berry, Hansenne, & Mikolajczak, 2010). Future studies are thus needed to

examine the influence of these strategies on the explosiveness and accumulation of positive emotions. Study 1 did not allow us to examine this topic as no positive feedback was offered and very few participants ever experienced the negative or neutral feedback as positive, whereas participants in Study 2 only reported negative events. Moreover, as emotion regulation strategies are affected by sociocultural factors (Mesquita, De Leersnyder, & Albert, 2014), future studies using diverse samples are needed to examine the generalizability of the present findings to non-western populations, as well as to increase our understanding of cultural differences in pattern of emotion unfolding. Finally, in both studies, participants retrospectively reported their emotional experience. We attempted to minimise the influence of memory biases by collecting information on emotion unfolding either immediately following the emotional event (Study 1) or at the end of the day (Study 2). Nevertheless, as memory biases might still play a role, future research may benefit from online data collection methods such as continuous recordings of physiological markers of emotional responding (e.g. heart rate or pupil dilation).

Although emotions are recognised as dynamic processes, they have rarely been studied in a dynamic way. In the present study, we measured the temporal unfolding of emotional experience in conjunction with a set of regulation strategies. Rumination was found to be a key process underlying emotion unfolding. These findings provide support for emotion regulation theories, which argue that rumination is a central mechanism underlying the temporal dynamics of negative emotions (Garnefski et al., 2001; Gross, 2015; Nolen-Hoeksema et al., 2008), and highlight the need for future emotion dynamics research focusing on the role of rumination.

Notes

1. For the original psychometric properties (internal consistency and test-retest reliability) of these questionnaires, see Table S1 in the Supplementary Information.
2. Keeping these four participants did not alter any of the conclusions we report.
3. None of the additional questionnaires pertained to emotion regulation but instead assessed personality and well-being. The full list of questionnaires is available upon request.
4. Dropping this first inclusion criterion did not alter any of the conclusions we report.
5. It is notable that, when entering feedback number as a linear and quadrative predictor of explosiveness and accumulation at level 1, we found evidence for a negative linear effect of feedback number on emotion explosiveness and accumulation (no evidence for a quadratic trend was found). Controlling for this linear trend did not alter any of the conclusions we report.
6. We ran a formal post-hoc power analysis using Monte Carlo simulation as implemented in the powerCurve function of the SIMR R package (v. 1.0.2; Green & Macleod, 2016). We entered the observed effect-size of brooding as a predictor of accumulation, revealing the power of Study 1 to be .65.
7. In the larger study, the 114 participants were recruited as follows: In an initial pre-screening, 403 individuals completed the Big Five Inventory (BFI). From these 403 respondents, 147 were selected using a stratified sampling approach to maximize variation on neuroticism (for a similar approach, see Koval et al., 2015), a strong predictor of emotional responding to events (Diener, Oishi, & Lucas, 2003) and of emotion regulation (Gross & John, 2003). From the 121 participants who accepted to participate, 1 did not respond to more than 50% of the five attention checks, and 6 missed more than 50% of the questionnaires, leaving a final sample of 114.
8. Participants were paid $0.60 for the BFI completion, $2 for the baseline survey, $1 per completion day, and a $3 bonus when they completed all seven daily questionnaires.
9. Most of the additional questionnaires did not pertain to emotion regulation but instead assessed personality and well-being (the full protocol is available upon request), with two exceptions: the ERQ (Gross & John, 2003) and an ERQ under construction based on a new emotion regulation taxonomy (Kalokerinos, Greenaway, Ceulemans, & Kuppens, 2016). These measures strongly overlapped with the emotion regulation measures already reported, and are therefore described in supplementary materials instead (see supplementary materials). These results did not alter any of our conclusions.
10. In Study 2, the correlation between emotion duration and emotion explosiveness ($r(480) = .10$, $p = .03$) as well as the correlation between emotion duration and emotion accumulation ($r(480) = .31$, $p < .001$) were significant. However, the modest size of these correlations indicates that explosiveness, accumulation and duration are distinctive temporal features.
11. Results remain highly similar whether group-mean or grand-mean centring. Likewise, controlling for the duration of emotional episode duration did not alter any conclusion.

Acknowledgments

The authors thank Kristof Meers (KU Leuven), Joke Heylen (KU Leuven), and Noémi Schuurman (Utrecht University) for their help with data analysis.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

The research leading to the results reported in this paper was supported in part by the Research Fund of KU Leuven (GOA/15/003) and by the Belgian Government – Interuniversity Attraction Poles programme (IAP/P7/06). Philippe Verduyn is supported as a postdoctoral fellow of the Research Foundation, Flanders – Fonds Wetenschappelijk Onderzoek (FWO). Elise Kalokerinos is supported by a Marie Sklodowska-Curie individual fellowship (No 704298) under the European Union's Horizon 2020 research and innovation programme.

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