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Bidirectional-Compounding Effects of Rumination and Negative Emotion in Predicting Impulsive Behavior: Implications for Emotional Cascades

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Abstract

Background—Influenced by chaos theory, the Emotional Cascade Model proposes that rumination and negative emotion may promote each other in a self-amplifying cycle that increases over time. Accordingly, exponential-compounding effects may better describe the relationship between rumination and negative emotion when they occur in impulsive persons, and predict impulsive behavior.

Methods—Participants who reported frequent engagement in impulsive behaviors monitored their ruminative thoughts and negative emotion multiple times daily for two weeks using digital recording devices. Hypotheses were tested using cross-lagged mixed model analyses.

Results—Findings indicated that rumination predicted subsequent elevations in rumination that lasted over extended periods of time. Rumination and negative emotion predicted increased levels of each other at subsequent assessments, and exponential functions for these associations were supported. Results also supported a synergistic effect between rumination and negative emotion, predicting larger elevations in subsequent rumination and negative emotion than when one variable alone was elevated. Finally, there were synergistic effects of rumination and negative emotion in predicting number of impulsive behaviors subsequently reported.

Conclusions—These findings are consistent with the Emotional Cascade Model in suggesting that momentary rumination and negative emotion progressively propagate and magnify each other over time in impulsive people, promoting impulsive behavior.

Keywords

emotional cascades; rumination; negative emotion; emotion dysregulation; chaos theory

Rumination, a cognitive process that involves repetitive and persistent thinking about upsetting problems, emotional experiences, and associated consequences (Nolen-Hoeksema, 1991; Nolen-Hoeksema et al., 2008; Martin & Tesser, 1996), has been broadly linked to many forms of psychopathology (Aldao, Nolen-Hoeksema, & Schweizer, 2010; Nolen-Hoeksema et al., 2007; Selby et al., 2008). Although there is still debate about what exactly

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rumination is and if it applies primarily to thinking about problems or to emotional experience such as depression (Watkins, 2008), numerous studies have found that rumination measured in various ways has harmful effects. Specifically, a number of experimental studies have indicated that engaging in rumination results in subsequent increases in negative emotion in depressed (Donaldson & Lam, 2004; Lavender & Watkins, 2004; Nolen-Hoeksema & Morrow, 1993), non-depressed (McLaughlin et al., 2007), and borderline personality disorder (BPD) samples (Selby et al., 2009). Negative emotion, a multifaceted intrapersonal experience characterized by subjective cognitive and physiological responses to an aversive situation lasting for a circumscribed timeframe (Mauss et al., 2005), has also been found to predict increases in rumination (Moberly & Watkins, 2004; Salovey, 1992). Thus, there may be a potential bidirectional, intensifying effect between rumination and negative emotion.

The Emotional Cascade Model (Selby et al., 2008; Selby & Joiner, 2009), a recent model that builds on this previous work, suggests that the relationship between rumination and negative affect is uniquely pernicious when it occurs in individuals who engage in impulsive behaviors. In these individuals, rumination is one component of a feedback process called an "emotional cascade," wherein negative emotion and rumination synergistically and progressively aggravate each other, resulting in an aversive experience that escalates rapidly (Selby & Joiner, 2013). In impulsive individuals, rumination and negative emotion may compound each other over time, with the influence of each of these variables on one another being stronger at higher levels than at lower levels. Thus, these relationships may be better described as exponential rather than linear. Furthermore, in the midst of an emotional cascade, some people may engage in impulsive behaviors (e.g., substance use, binge eating, fighting, or self-injury) because these behaviors provide potent physical sensations that may distract from rumination (e.g., effects of a drug, taste, pain, sight of blood, etc.) and short-circuit the cascade. Indeed, a number of studies have linked emotional cascades to the experience of impulsive behaviors (Arbuthnott, Lewis, & Bailey, in press; Selby et al., 2009; Selby & Joiner, 2013; Tuna & Bozo, 2014). The model also suggests that those who experience emotional cascades are at higher risk for psychopathology (Selby & Joiner, 2009). The purpose of the current study was to replicate previous findings on the bidirectional relationship between rumination and negative emotion in impulsive individuals, examine synergistic and exponential-compounding associations between them over time, and to predict subsequent engagement in impulsive behaviors using experience sampling.

The Effects of Rumination on Negative Emotion Over Time

Rumination was originally conceptualized as a trait construct, with individuals exhibiting consistent levels of rumination over time and across situations (Nolen-Hoeksema, 1991). Yet, evidence has emerged indicating that even those with elevated ruminative tendencies may experience varying levels of rumination depending on individual factors, developmental stage, or situational context (Bagby et al., 2004; Caprara, et al., 2007; Hankin, 2008; McCullough, Bono, & Root, 2007). One study found that some individuals exhibit "instability" of rumination, with his or her level of rumination fluctuating dramatically over the course of daily experience across multiple days, and that instability of rumination predicted self-injurious behavior (Selby et al., 2013). Thus, although it can still be useful to

think of general ruminative tendencies as a trait, it's important to recognize that individuals with high trait levels of rumination may still exhibit very diverse levels of rumination across time and situations. However, rumination has primarily been studied with single-assessment self-report measures, experimental methods, or longitudinal methods extending over years, neglecting the examination of rumination over the course of hours. Consequently, understanding of the temporal dynamics of rumination remains unclear.

The short-term effects of rumination on negative emotion are not fully understood. In the original conceptualization, one of the key components of rumination is that it is thought to increase and prolong negative emotion (Nolen-Hoeksema, 1991). Several experimental studies have corroborated this theory, finding that participants randomized to various rumination conditions report significantly increased negative emotion relative to control conditions (McLaughlin et al., 2007; Selby et al., 2009). However, few studies have examined this relationship between rumination and negative emotion as it naturally occurs in daily life. Experience sampling methodology may address this limitation, as it involves participants recording emotional and cognitive experiences multiple times daily over multiple days, allowing for examination of temporal associations between rumination and negative emotion over time. In one such study, rumination predicted increased levels of *concurrent* negative emotion (Takano & Tanno, 2011), although subsequent increases were not examined. Another found that daily rumination about an unpleasant event increased daily negative emotion (Genet & Siemer, 2012).

While rumination seems to increase negative emotion, there also is evidence that negative emotion increases rumination. Using mood inductions and measures of self-awareness, Salovey (1992) found that increases in both happy and sad moods increased self-focused attention, which is a construct highly related to rumination (Watkins, 2008). Accordingly, previous studies have indicated that increasing self-focused attention intensifies affective arousal (Carver, Blaney, & Scheier, 1979; Scheier & Carver, 1977), indicating that rumination and negative affect might have a reciprocal relationship. One recent study examined this relationship between rumination and negative emotion over time in more detail, using experience sampling with an adult sample (Moberly & Watkins, 2008). Participants received a detailed explanation of rumination and then rated their rumination and negative emotion levels multiple times per day for a period of one week using digital watches. Through cross-lagged analyses, this study demonstrated that levels of negative emotion and rumination at one momentary assessment significantly predicted negative emotion and rumination at the subsequent assessment. Together, these studies demonstrate that rumination and negative emotion may have a bidirectional relationship; however, further clarification is needed to fully understand how the interplay between rumination and negative emotion unfolds over time.

Exponential and Synergistic Relationships between Rumination and Negative Emotion

The majority of research on rumination and negative emotion has examined linear relationships between the two. The Emotional Cascade Model proposes two important

modifications of this association in impulsive individuals: 1) the experience of both rumination and negative emotion has a synergistic effect on subsequent negative emotion and rumination, resulting in a rapidly escalating aversive experience relative to when only one of the two factors is elevated, and 2) because of this synergistic effect, the temporal associations between rumination and negative emotion are better described as exponential rather than linear.

In an emotional cascade, rumination and negative emotion are thought to propagate each other in a vicious cycle, progressively magnifying each other. As a result of this self-amplifying positive feedback loop, some people may experience a rapidly escalating and extremely aversive state. Accordingly, the effects of rumination on negative emotion over time should be stronger at higher levels than at lower levels, and vice versa.

Theoretical support for this viewpoint of exponential-compounding effects comes from the literature on chaos theory and complexity (Gleick, 1997; Waldrop, 1993), which has served as a theoretical foundation for the development of the Emotional Cascade Model (Selby & Joiner, 2009). In chaos theory, a common effect is found in many dynamic systems known as "sensitive dependence on initial conditions," frequently referred to as the *butterfly effect* (Eckmann & Ruelle, 1985). What this term highlights is that, in dynamic systems, positive feedback processes can exponentially magnify small differences in the initial parameters of a system, resulting in potentially different trajectories of the system. In this way, small differences become amplified. A similar process may occur between rumination and negative emotion during emotional cascades, where differences in the baseline association between rumination and negative emotion become exponentially amplified over time, particularly among individuals with high levels of impulsivity, such that those with higher baseline associations experience worse outcomes. However, no studies to date have used experience sampling data to examine synergistic effect or exponential effects between rumination and negative emotion, or used such data to predict subsequent impulsive behaviors.

The Emotional Cascade Model attempts to build on and extend the traditional construct of rumination (Martin & Tesser, 1996; Nolen-Hoeksema, 1991), rather than redefine it, by highlighting a dynamic process that unfolds over time for some people and involves rumination as a necessary but ultimately insufficient component. In many ways this model is unique and builds on Nolen-Hoeksema's (1991) original conceptualization of rumination. Although traditional conceptualizations of rumination hypothesize that rumination increases negative emotion, it has not been clarified whether synergistic increases in rumination and negative emotion also increase rumination, or if this process continues in a progressive fashion over time to ultimately lead to extreme emotional experiences. Instead, most traditional conceptualizations indicate that rumination would elevate and maintain negative emotion at a high, but potentially stable level, thus prolonging distressed moods. Furthermore, emotional cascades can be viewed as an individual differences process, wherein some people will experience differential strength in the associations between rumination and negative emotion, with those individuals with stronger associations being more prone to emotional cascades and impulsive behavior. In contrast, traditional views of rumination suggest that people can range on levels of the trait, but the strength of

rumination's influence on negative emotion is generally viewed to be constant for those with elevated rumination levels. Finally, the Emotional Cascade Model is fundamentally connected to impulsive behavior, something that is not a component of most conceptualizations of rumination (even though multiple studies have linked rumination to impulsive behavior).

Emotional Cascades and Impulsive Behaviors

Impulsive behaviors have been defined as any behavior engaged in for short-term effects but which ultimately result in long-term negative consequences for the individual (Selby & Joiner, 2009). The Emotional Cascade Model differs from traditional conceptualizations of rumination in that emotional cascades are inextricably linked to impulsive behaviors (also called dysregulated behaviors), and that an impulsive behavior is in many ways a natural response to an emotional cascade. If everyone who ruminated experienced such exponential increases in negative emotion, then a much greater proportion of people would have trouble with impulsive behavior. Emotional cascades, however, may be specific to impulsive individuals. Without intervention, a majority of emotional cascades may ultimately lead to impulsive behaviors because they are aversive experiences that are difficult to tolerate. Impulsive behaviors might provide physical distraction that short-circuits the emotion cascade by reducing rumination.

When considering the relationship of emotional cascades and impulsive behaviors, it's helpful to refer back to chaos theory. Although the butterfly effect can result in a wide array of different trajectories based on initial parameters, outcomes are not entirely unpredictable. Oftentimes, after passing a certain threshold, the dynamic effects of a system will gravitate toward a steady state that is more balanced and predictable. This effect is often known as an "attractor" state (Eckmann & Ruelle, 1985; Gleick, 1997). A common conceptualization of this phenomenon is that drops of water can take different paths when falling down an incline, but ultimately form into a pool at the basin. In a similar sense, impulsive behaviors could be fixed-point attractor states[1] toward which people experiencing emotional cascades are drawn, as the exponential-compounding effects of negative emotion and rumination may become or seem unbearable. The impulsive behavior stabilizes the emotional system, by interfering with the compounding effects and providing some relief. Accordingly, we expect that as people express higher levels of both negative emotion and rumination, they will experience synergistic effects of both that make them more likely to engage in impulsive behaviors than if only one was high.

Recent empirical evidence suggests that emotional cascades (operationalized as an interaction between momentary rumination and negative emotion levels) reported during momentary recordings predict the occurrence of an impulsive behavior at a subsequent recording 2-3 hours later (Selby & Joiner, 2013). However, to date no research has examined synergistic and exponential effects of rumination and negative emotion in predicting the

[1]Impulsive behavior could also arguably constitute a strange attractor, predictable bounded outcomes, which has complex but still potentially given that impulsive behaviors frequently cluster, can repeat themselves, and can initiate other behaviors, as in the case of binging and purging; however discussion of this concept is beyond the scope of the current manuscript.

occurrence of multiple impulsive behaviors, or if impulsive behaviors may serve as an attractor state toward which those experiencing emotional cascades may be drawn.

Current Study

The goal of the current study was to increase our understanding of the effects of rumination and negative emotion on each other over time and in impulsive individuals using experience sampling. Based on previous conceptualizations of rumination and the Emotional Cascade Model, we formulated the following hypotheses: 1) elevations in rumination would last for extended periods of time, and elevated levels at one assessment would predict elevations in rumination multiple assessments later, 2) elevated levels of rumination at one assessment would predict increased levels of both negative emotion at the subsequent assessment, 3) elevated levels of negative emotion would predict increased levels of both rumination and negative emotion at the subsequent assessment, 4) the effects of rumination and negative emotion on levels of rumination and negative emotion at the subsequent assessment would be characterized by exponential functions, with the relationships between these variables being stronger at high levels than low levels, 5) there would be synergistic effects between levels of negative emotion and rumination, such that the *interaction* between negative emotion and rumination at one assessment would significantly predict increased levels of both rumination and negative emotion at the subsequent assessment, and 6) the synergistic effects of rumination and negative emotion would predict engagement in impulsive behaviors at the subsequent assessment such that those with high levels of both would report the most impulsive behaviors.

Method

Participants

Participants for this study were 47 impulsive adults (66% female) from a southern university (N=20) and the surrounding community (N=27). Because this study focused on understanding cognitive and emotional factors involved in impulsive behavior, criteria for inclusion included: 1) Self-report of at least four impulsive behaviors (non-suicidal self-injury, arguments, physical fights, binge-eating/vomiting, drug use, or alcohol binges) over the last two weeks, and 2) No imminent risk of suicide as indicated by absence of suicidal intent and a suicide plan as assessed with a clinical suicide risk assessment. No participants were excluded due to concerns about suicide risk. This study was approved by the university institutional review board, and all participants provided informed consent.

The sample was diverse, with 8.5% reporting Hispanic ethnicity, and a racial composition of 68.1% white/European, 19.1% black/African American, 6.4% Asian, 2.1% Native American, and 4.3% multiracial. The average age of participants was 24.25 (SD=9.77). Comparisons between the student and community participants on baseline demographic variables and covariates used in the analyses (e.g., age, sex, comorbid diagnoses, currently in therapy, using psychotropic medication) indicated that the only significant differences were that the student sample was younger ($F_{1, 46}$=10.60, p<.05). This suggests that differences were small enough to warrant combining them for subsequent analyses. In order to enhance compliance with the daily monitoring, student participants were offered course credit for

their participation and were offered the opportunity to receive additional course credit for completing at least 80% of the random daily assessments. Community participants were compensated $50 for completing the study, and an additional $50 for at least 80% compliance.

Procedure

Recruitment flyers were posted on community bulletin boards, in local clinical treatment centers, and online. All participants first underwent an initial screening session to ensure they met study inclusion criteria, and all who presented for the in-person screening met inclusion criteria for the study. Participants then completed structured clinical interviews for Axis I diagnoses and BPD, and received training in the use of the digital recording devices and assessment program (Palm Zire 31 model PDAs with Satellite Forms Software). After the first lab visit, all participants completed two practice days of monitoring to ensure that they understood how to use the program. Participants then returned to the lab for study personnel to download their data, confirm they were following the protocol and answer any questions. The two practice days were not included with the final data. Subsequently, all participants completed 14 days (two consecutive weeks) of actual monitoring, during which they completed 5 daily randomly alarmed assessments. Participants returned to the lab at the end of each week for data download data and examination of protocol adherence.

Baseline Measures

Clinical Diagnostic Interviews: Participants were assessed for clinical diagnoses because rumination is a common problem across many disorders (Aldao et al., 2010), including depression and BPD (Selby et al., 2009). In the current study, because all participants were recruited based on difficulties with impulsivity we also wanted to control for clinical diagnoses to ensure those were not solely accounting for the effects. Accordingly, we controlled for major depression disorder (MDD) diagnosis and BPD as covariates in all analyses. All participants completed interviews for acute psychiatric disorders, such as depression and anxiety, using Mini International Neuropsychiatric Interview (MINI; Sheehan et al., 1998). In this sample, 14 (30%) individuals had current MDD diagnoses, 17 (36%) had generalized anxiety disorder, 6 (13%) had current panic disorder, 5 (11%) had social phobia, 8 (17%) had posttraumatic stress disorder, 16 (34%) had a current alcohol use disorder, and 19 (40%) had a current substance use disorder. Inter-rater reliability was good for all Axis I diagnoses (over $\kappa = .73$; for more details see Selby & Joiner, 2013). Participants were also assessed for BPD symptoms using the Structure Clinical Interview for DSM-IV Axis II Personality Disorders (SCID-II; First et al., 1997). There were 16 participants who met full criteria for BPD in the sample (34%), and the average number of BPD symptoms was 5.50 (SD=1.85). Inter-rater reliability for BPD in this sample was good (k=.81).

***Cognitive Emotion Regulation Questionnaire* (CERQ; Garnefski et al., 2001):** This trait measure of cognitive emotion regulation processes includes a subscale on rumination, which was used to assess convergent validity for the experience sampling rumination assessment and as a covariate in all analyses. This subscale had good internal consistency in this sample (α=.80).

Momentary Assessments—The PDAs were programmed to "beep" or alert the participant five times at random between 9:00am and 9:00pm every day, approximately every 2-3 hours. At each of these alarms the participant completed the PDA questionnaire (below), which generally took under three minutes. Participants were informed that they needed to respond to the assessment within 1 hour for the record to count toward the compliance incentive previously described. The participants had the opportunity to "snooze" the PDA if they were in a situation in which completing the form was problematic (e.g., driving); doing so silenced the beeping for 5 minutes.

Affect Assessment: Participants rated their momentary experience of positive and negative emotions "RIGHT NOW," using items derived from the PANAS (Watson, Clark, & Tellegen, 1988). Negative emotions included sad, angry, worried[2], and ashamed, which were rated from 1 (low) to 5 (high). In the current study, items regarding negative emotion were summed for each monitoring assessment. These items demonstrated good reliability when within-person variance ratios were examined to determine the overall reliability of item responses across days (R_{KF}; Cranford et al., 2006), with scores ranging from .83 for sad and .99 for angry.

Rumination Assessment: Participants reported to what extent they were "CURRENTLY thinking" certain thoughts on a scale from 1 (not at all) to 10 (very much so). The rumination-specific questions were: "a currently upsetting problem," "upsetting memories," "the emotions that I am feeling," and "negative future situations." These questions were summed into a single scale of rumination and averaged for each day of monitoring[3]. The items for this scale were derived from pre-existing measures for trait rumination including the CERQ (Garnefski et al., 2005) and the Response Styles Questionnaire (RSQ; Nolen-Hoeksema & Morrow, 1991) and modeled after other experience sampling studies that have examined rumination (Moberly & Watkins, 2008). The item regarding thinking about negative future situations was included because recent theoretical accounts have considered thinking about future problems as a future-oriented form of rumination (Ehring & Watkins, 2008; McEvoy et al., 2013), and in our previous work we have found future oriented forms of rumination to load significantly onto a single latent variable with other forms of rumination (Selby et al., 2008; 2009). Average scores on this momentary measure of rumination across monitoring for participants had significant positive correlations with baseline levels of trait rumination as measured by the CERQ (r=.42, p<.001). This correlation between the baseline rumination measure and the momentary measure is consistent with other studies on rumination assessed using experience sampling (Moberly &

[2]It is important to note that using the term "worry" as interchangeable with "anxiety" is potentially problematic in this study, as worry potentially denotes cognitive evaluation of anxiety or fear. Accordingly, we re-analyzed all results using a negative emotion summary score calculated without the worry item, and there were no significant changes or decreases in predictor magnitude. Furthermore, the three-item and four-item negative emotion scales correlated highly (r=.94, p<.001), and worry was not perfectly associated with rumination about the future (r=.62, p<.001), suggesting that the inclusion of worry did not solely account for findings. Similarly, because there is evidence that worry is a form of rumination we included focusing on "future problems" as a part of our rumination measure. To ensure that including this item was not problematic, we re-examined all analyses with a rumination scale not including this item and all analyses again turned out essentially the same.

[3]Although this assessment also included thoughts about "solving a problem," this item was not included in the scale with the other rumination items because doing so decreased internal consistency of the items from .79 to .59, and this item did not demonstrate strong correlations with the other rumination items. These findings suggest that the momentary rumination scale was not contaminated by problem solving efforts.

Watkins, 2008). Although there may be other methods of assessing rumination with experience sampling, such as assessing the tendency for thoughts to linger on one continuing theme throughout the duration of the day, the current methods are in line with the concept of rumination as proposed by focusing on a tendency to frequently think about multiple upsetting problems. When within-person variance ratios were examined to determine the overall reliability of item responses across days, all rumination items demonstrated good reliability (ranging from R_{KF} = .89 for rumination about emotions to R_{KF} =.95 for rumination about the past).

Impulsive Behavior Assessment: At each assessment participants were asked to complete a checklist recording if they had engaged in any of the following behaviors since the previous assessment: binging on food, reckless driving, physical fights, binging on alcohol, self-injury, marijuana use, impulsive shopping, yelling at someone, throwing something, slamming a door, hanging up on someone, or insulting someone. During the baseline visit, participants were provided with definitions of each of these behaviors (e.g., a binge episode involves eating more food than most people would over a two hour period and feelings of loss of control) and all verified their understanding of these definitions. Behaviors were summed into a count variable of total number of behaviors at each assessment (Selby et al., 2008; 2009; Tuna & Bozo, 2014).

Data Analytic Strategy—The data from this study were longitudinal in nature, with each individual assessed multiple times over multiple days, and multiple observations were nested within each participant. In order to account for this nesting and non-independence of observations, we analyzed these data using linear mixed models (Raudenbush & Bryk, 2002). This analytic approach handles repeated measures in participants with restricted maximum likelihood estimation and accounts for differing numbers of observations within participants. Within these models, we primarily examined within-person analyses to determine the effects of rumination and negative emotion over time. In all analyses we specified random intercepts. In addition to accounting for the nesting structure of these data, we also examined our independent continuous variables first as fixed effects, and then as random effects. Fixed effects allowed us to examine our primary hypotheses regarding the relationships between rumination and negative emotion. By also examining random effects we were able to determine if there was significant variance in the relationships between rumination and negative emotion between participants.

In order to examine the effects of rumination and negative emotion on each other over time, we created lag variables for rumination and negative emotion. Lag variables allow for the use of a previous recording in the prediction of a subsequent recording. Because lag variables were generated within each day for each participant, recordings that occurred the previous day for that individual were not included in the analyses. Furthermore, in order to examine the persistence of rumination over multiple recordings we created multiple lag variables, which allowed us to examine the effects of rumination 3 recordings prior (Lag[T-3]; 7-9 hours between assessments), 2 recordings (Lag[T-2]; 4-6 hours between observations), and one recording prior (Lag[T-1]; 2-3 hours between assessments) on current rumination (Real-Time). For our analysis of the exponential effects of lag rumination and lag

negative emotion on subsequent levels of both variables, we included both the linear and exponential effects, the latter of which was generated by exponentiating each lag variable. Because the estimates provided in mixed models are not directly interpretable for curvature estimates, we also provide the curve estimates provided by the SPSS curve estimation model. In order to provide a test of variance accounted for, we utilized the hierarchical linear regression module and first entered the lag linear effect, and then in step two we entered the lag exponential effect, thus parsing and testing for significant variance between the effects. We also examined interactions between lag rumination and lag negative emotion to predict subsequent levels of both rumination and negative emotion, allowing for the examination of synergistic effects between variables. Finally, due to potential multicolinearity between rumination and negative emotion, both were grand mean centered.

For the final hypothesis, regarding prediction of impulsive behaviors, we examined generalized linear mixed models in which we used lagged predictors to predict the total number of all impulsive behaviors reported by each participant at the current signal[4]. Because this outcome variable was a count of the various behaviors, it was not normally distributed and we utilized a log link function with a Poisson distribution. Like the previous analyses, models were specified with random intercepts and the interaction was examined after the main effects.

In order to ensure that other variables associated with rumination were not accounting for the observed effects, we conducted follow-up analyses for each hypothesis controlling for time in study, lag time between assessments, trait rumination, age, gender, current depression diagnosis, and BPD. We also examined the cross-level interaction of sex, depression and BPD with within-person lag predictors because of their known associations with rumination. Primary interactions were examined hierarchically, after controlling for main effects, covariates, and other cross-level interactions. Analyses were conducted in the *mixed* module of SPSS version 20.

Results

Preliminary Analyses

During the 2-week monitoring period, participants completed 3,118 random daily assessments (M=65 recordings per participant). Average compliance rates were over 90%. The ICC for rumination was .193, and for negative emotion it was .332, indicating that most variance for rumination and negative emotion was within-person, but 19.30% of the rumination variance and 33.2% of the negative emotion variance was between persons.

When concurrent reports of rumination and negative emotion were examined, they demonstrated a significant large correlation ($r=.67$, $p<.001$). Although they were highly correlated, they were not perfectly correlated, suggesting some divergence in the

[4]A similar analysis of the synergistic effects of momentary negative emotion and rumination was previously reported in Selby & Joiner (2013), but there are important distinctions between the previous analysis and the current analysis. The previous analysis examined a 3-way interaction between lag rumination, lag negative emotion, and BPD symptoms in predicting the onset of any one of the impulsive behaviors, and was significant. The current analysis, however investigated the 2-way interaction between lag negative emotion and lag rumination in predicting the report of multiple impulsive behaviors at one assessment. Furthermore, this analysis examined the exponential effects of the interaction components – analyses that have not been previous reported.

measurement of our constructs. There were significant effects of time participating in the study, indicating that participants reported decreases in level of negative emotion ($\gamma = -.031$, SE=.010, $t(3070) = -3.19$, $p<.01$, d=.12), rumination ($\gamma = -.077$, SE=.025, $t(3070) = -3.10$, $p<.01$, d=.11), and impulsive behaviors over the two-week monitoring period ($\gamma = -.011$, SE=.003, $t(3070) = -4.41$, $p<.001$, d=.16). Accordingly, we controlled for time in the primary analyses to ensure that effects were not primarily accounted for by the beginning of the study. Because time of day has been found to impact negative emotion (Takano & Tanno, 2011), we also examined if there were differential effects for assessments completed in the morning versus the afternoon. The time of day variable was not a significant predictor for any of the primary Level-1 variables.

Persistence of Rumination Over Time

Our first hypothesis was that ruminative thoughts would persist over time, and that rumination at one assessment would significantly predict elevated levels of rumination at multiple subsequent assessments. For interpretation purposes, all lag variables were examined in relation to current rumination, which was typically assessed in the late afternoon or evening for the present analyses. In line with this hypothesis, there was a significant effect of lag-rumination on current rumination approximately 2-3 hours later ((Lag[T-1]), γ=.245, SE=.014, $t(3106)$=17.64, $p<.001$, d=.72). This effect was unchanged with covariates. When we examined the 2nd lag rumination variable (approximately 4-6 hours between assessments), there was also an effect of lag-rumination on current rumination ((Lag[T-2]), γ=.074, SE=.015, $t(2380)$=4.84, $p<.001$, d=.18), even after accounting for the previous rumination level. Finally, when examined at the 3rd lag rumination variable (approximately 7-9 hours between assessments), there was again a significant effect of lag-rumination on later rumination ((Lag[T-3]), γ=.035, SE=.018, $t(1699)$=2.03, p=.042, d=.08) even after accounting for the two rumination levels in between, and trait rumination level. The effects of rumination between the four assessments (ranging from 7-9 hours) for each participant are displayed in Figure 1, which displays the means for each participant's level of rumination over time. This figure demonstrates that many participants experienced increases in rumination that lasted for several assessments throughout the day, with the rumination at the first assessment (occurring in the morning) predicting rumination four assessments later (typically occurring in the late afternoon or evening). These findings indicate that the effects of rumination are significantly associated with rumination many hours later, supporting the notion that rumination can persist over time. Findings also remained unchanged when including the lag time variable to account for time differences between observations.

Linear and Exponential Predictive Associations with Negative Emotion Over Time

Our second hypothesis was that elevations in rumination at one assessment would predict elevated negative emotion at the subsequent assessment, in line with previous findings (Moberly & Watkins, 2008). This hypothesis was supported, as there was a significant linear effect of lag- rumination predicting increased current emotion (γ=.136, SE=.007, $t(2405)$=17.91, $p<.001$, d=.73). In addition to examining the linear effects of rumination on negative emotion over time, we also examined exponential effects. The exponential rumination term was significant ($\gamma = 2.38\text{x}10^{-13}$, SE=$1.164\text{x}10^{-13}$, $t(2382)$=8.46, $p<.001$,

d=.21; curve estimates: b=.020, SE=.001, t(3116)=23.66, p<.001; linear r^2=.07, p<.001, additional exponential r^2=.09, p<.001.), even when accounting for the linear effect, supporting our fourth hypothesis. Furthermore, when the model was re-analyzed with random effects there was a significant random intercept (σ^2=2.616, SE=.608, Wald Z=4.30, p<.001), and significant random linear effect (σ^2=.020, SE=.004, Wald Z=4.27, p<.001), but the random exponential slope variance was not significant. This finding indicated that some participants exhibited differential strength in their baseline associations between lag-rumination and current negative emotion (intercept) and the degree to which this association increased at higher levels (e.g. slope), change which was best captured by a fixed exponential effect. Figure 2 displays the exponential function with the random intercept upper- and lower-bounds, and demonstrated that people who started with high lag rumination exhibited exponentially increased current rumination, and that at lower initial levels people showed diminished current negative emotion. This finding supported the hypothesis that rumination at higher levels may have a greater association with subsequent negative emotion than at lower levels. These effects were unchanged when accounting for trait rumination, lag-negative emotion, gender, current depression, BPD, lag time, day of monitoring, and time of day. We also examined cross-level interactions between level-2 predictors, and found that the predictive association between lag rumination with current negative emotion was stronger for women (γ=.090, SE=.016, t(2321)=5.56, p<.001, d=.23), and for those with a BPD diagnosis (γ=.076, SE=.015, t(2321)=5.22, p<.001, d=.21), but not for those with depression.

Lag negative emotion also had significant linear (γ=.505, SE=.018, t(2370)=13.94, p<.001, d=.57) and exponential (γ=1.453x10^{-8}, SE=1.936x10^{-9}, t(2370)=7.50, p<.001, d=.31; curve estimates: b=.09, SE=.002, t(2370)=74.13, p<.001; linear r^2=.31, p<.001, additional exponential r^2=.16, p<.001.) predictive associations with current negative emotion. Investigation of random effects indicated a significant random intercept (σ^2=1.06, SE=.349, Wald Z=3.025, p<.01), and a significant random linear effect (σ^2=.15, SE=.035, Wald Z=4.45, p<.001). However, the random exponential effect was not significant. Effects held beyond covariates. These findings were similar to those for lag rumination, in that the effects of lag negative emotion on current negative emotion were best characterized by a fixed exponential function with a random intercept. Figure 2 displays this function and indicates that those who had high negative emotion reported exponentially higher negative emotion at the subsequent assessment.

When lag rumination and lag negative emotion were run simultaneously, with both linear and exponential predictors, all four terms were significant (linear lag rumination: γ=.033, SE=.010, t(2326)=3.35, p<.01, d=.14; linear lag negative emotion: γ=.412, SE=.027, t(2326)=15.39, p<.001, d=.63; exponential lag rumination: γ=2.196x10^{-13}, SE= 1.172x10^{-13}, t(2326)=6.94, p<.001, d=.28; exponential lag negative emotion: γ =6.421x10^{-9}, SE= 1.974x10^{-9}, t(2326)=3.25, p<.01, d=.13). These findings indicated that both rumination and negative emotion contributed beyond the shared effects of the other.

Linear and Exponential Predictive Associations with Rumination Over Time

Similar to the previous set of analyses, in these analyses we predicted current rumination using lag negative emotion. There was a significant fixed linear effect of lag negative emotion in predicting current rumination (γ=1.010, SE=.049, t(2326)=20.56, p<.001, d=.84), as well as a fixed exponential effect beyond the linear effect (γ=2.358x10^{-8}, SE= 5.022x10^{-9}, t(2326)=4.70, p<.001, d=.19; curve estimates: b=.095, SE=.004, t(2407)=26.22, p<.001; linear r^2=.13, p<.001, exponential r^2=.09, p<.001.), supporting hypotheses three and four. When examined with random effects, there was a significant random intercept (σ^2=13.200, SE=3.117, Wald Z=4.24, p<.001), as well as a significant random linear slope variance (σ^2=.875, SE=.217, Wald Z=4.03, p<.001). The random exponential slope variance was not significant, indicating that the exponential association between lag negative emotion and current rumination was not stronger for some than others. Figure 3 displays the exponential function of lag negative emotion on current rumination, and supported our third hypothesis that negative emotion at higher levels predicted exponentially more subsequent rumination, beyond covariates. When level-2 moderators were examined, significant cross-level interactions indicated that the relationship between lag negative emotion on rumination was stronger for women (γ=.66, SE=.11, t(2321)=5.98, p<.001, d=.25), and for those with a BPD diagnosis (γ=.403, SE=.098, t(2321)=4.11, p<.001, d=.17).

Although the effects of lag rumination on current rumination were reported above, we also examined exponential effects here. The fixed exponential effect of lag rumination on current rumination was significant (γ=3.768x10^{-13}, SE= 1.414x10^{-13}, t(2403)=6.67, p<.001, d=.27; curve estimates: b=.034, SE=.001, t(3115)=27.57, p<.001; linear r^2=.09, p<.001, additional exponential r^2=.11, p<.001), as expected. When random effects were examined, there was a significant random intercept (σ^2=7.854, SE=2.093, Wald Z=3.752, p<.001), and random linear slope variance (σ^2=.159, SE=.037, Wald Z=4.31, p<.001), but not a random exponential slope. The addition of covariates did not significant alter these findings. Examination of cross-level interactions indicated that the predictive association of lag rumination on current rumination was stronger for women (γ=.205, SE=.040, t(2321)=5.11, p<.001, d=.21), and for those with a BPD diagnosis (γ=.129, SE=.036, t(2321)=3.56, p<.001, d=.15).

When lag rumination and lag negative emotion were run simultaneously predicting current rumination, with both linear and exponential predictors, all four terms were significant (linear lag rumination: γ=.328, SE=.026, t(2326)=12.56, p<.001, d=.52; linear lag negative emotion: γ=.365, SE=.070, t(2326)=5.23, p<.001, d=.22; exponential lag rumination: γ=4.157x10^{-13}, SE= 1.451x10^{-13}, t(2326)=7.00, p<.001, d=.29; exponential lag negative emotion: γ=2.014x10^{-8}, SE= 5.185x10^{-9}, t(2326)=3.89, p<.001, d=.16). This finding indicated that both contributed beyond the shared effects of the other, and that lag rumination and lag negative emotion both had significant and unique predictive associations with subsequent rumination.

Synergistic Effects of Rumination and Negative Emotion Over Time

To examine our fifth hypothesis, the synergistic effects of rumination and negative emotion, we entered the interaction term between the two variables into mixed models with real-time

rumination and negative emotion as the dependent variables. After accounting for main effects of lag negative emotion and lag rumination, there were significant effects beyond covariates for the interaction term on both real-time negative emotion (γ=.016, SE=.0009, t(3098)=17.539, p<.001, d=.63) and real-time rumination (γ=.023, SE=.002, t(3102)=11.68, p<.001, d=.42). When these interactions were graphed out, as displayed in Figure 4, findings clearly supported the hypothesis that those with higher levels of both lag negative emotion and lag-rumination would report even higher levels of real-time negative emotion and rumination.

Effects of Rumination and Negative Emotion on Engagement in Impulsive Behaviors

When exponential associations were examined between rumination and negative emotion in predicting current impulsive behaviors, there were also significant fixed exponential effects for both lag rumination (γ=1.164x10^{-13}, SE= 1.044x10^{-13}, t(2326)=4.70, p<.001, d=.20; curve estimates: b=.015, SE=.002, t(2407)=6.65, p<.001, r^2=.02) and lag negative emotion (γ=2.633x10^{-9}, SE= 5.137x10^{-10}, t(2326)=3.69, p<.001, d=.15; curve estimates: b= .069, SE= .006, t(2407)=23.17, p<.001, r^2=.05). When examining lag rumination with random effects, there were significant random intercept (σ^2=.666, SE=.003, Wald Z=3.70, p<.001) and linear slope (σ^2=.003, SE=.001, Wald Z=2.63, p<.01) variances, but not an exponential slope variance. Similarly, for lag negative emotion there were significant random intercept (σ^2=.347, SE=.158, Wald Z=2.22, p<.05) and linear slope variances (σ^2=.015, SE=.005, Wald Z=2.94, p<.01), but not exponential. Figure 5 displays the functions for lag rumination and negative emotion predicting impulsive behaviors, along with the upper and lower bounds rising from the random intercepts, indicating that for some increases in predictors was exponentially associated with current report of more behaviors. When cross-level interactions were examined, significant interactions indicated that women moderated both predictors at a higher level (lag negative emotion: γ=.049, SE=.011, t(2320)=4.36, p<.001, d=.18; rumination: γ=.010, SE=.003, t(2320)=3.18, p<.001, d=.13), as did those with BPD (lag negative emotion: γ=.038, SE=.005, t(2320)=7.67, p<.01, d=.32; lag rumination: γ=.014, SE=.002, t(2320)=7.16, p<.05, d=.30).

Finally, to examine our sixth and final hypothesis that lag rumination and lag negative emotion have synergistic effects in predicting subsequent impulsive behaviors, we examined a generalized mixed model with number of impulsive behaviors reported as the outcome variable. This analysis indicated that there were main effects, beyond covariates, for both lag rumination (γ=.039, SE=.009, t(2321)=4.58, p<.001, d=.19) and lag negative emotion (γ=.076, SE=.019, t(2321)=3.97, p<.001, d=.17), such that higher levels of each predicted more impulsive behaviors. Furthermore, there was a significant interaction between lag rumination and lag negative emotion (γ=.004, SE=.001, t(2320)=10.84, p<.001, d=.45) so that higher levels of both predicted the highest number of impulsive reported. Figure 6 demonstrates the interactions.

Discussion

The Emotional Cascade Model builds on the current literature on rumination, and proposes that rumination and negative emotion promote impulsive behavior and work synergistically

to increase subsequent levels of both in impulsive people. In this study, we examined the bidirectional-compounding effects of rumination and negative emotion over time in an impulsive sample using experience sampling methods. Using cross-lagged analyses, we demonstrated that elevated rumination and negative emotion predicted later elevated rumination and negative emotion, and that these associations were characterized by significant exponential functions. Furthermore, we found that rumination and negative emotion significantly and exponentially predicted subsequent impulsive behaviors, and that there were synergistic effects between rumination and negative emotion that predicted subsequent elevations in each other as well as more subsequent impulsive behaviors. The findings of this study for both synergistic and exponential effects between negative emotion and rumination on subsequent negative emotion, rumination, and impulsive behavior indicate that not only do rumination and negative emotion potentially synergistically influence each other to a higher level, but that these effects may compound each other in a progressive manner that may ultimately promote extreme emotional responses and subsequent impulsive behavior.

The identification of varying baseline associations (e.g. random intercepts) between momentary rumination and negative emotion and exponential predictive associations between rumination and negative emotion on each other, as well as on impulsive behavior, demonstrates that rumination may take on a different form in some individuals, perhaps in unique ways for those who are impulsive. Traditional conceptualizations of rumination posit that rumination may increase and maintain negative emotion at an elevated yet stable level. The findings of this study support this notion, but also suggest it may potentially differ in impulsive samples where the compounding effects of negative emotion may progressively increase, in many cases culminating in impulsive behavior. These findings provide preliminary evidence differentiating emotional cascades from traditional conceptualizations of rumination. However, because this study did not include a control group of non-impulsive individuals, we cannot conclusively determine if this process is fundamentally distinct to impulsive individuals.

Another significant contribution of this study was that we examined random effects for all analyses, including both random intercepts and random slopes. Accordingly, there were also significant random linear effects to these associations, suggesting that the association between rumination and negative emotion was stronger at higher levels for some participants than others, and further supporting the fixed exponential effect. These findings can be interpreted thusly: 1) People appear to differ in the strength of their baseline associations between rumination and negative emotion, as well as the ability of these variables to predict impulse behaviors, and 2) exponential associations between these variables magnify even small differences in this baseline association such that those with higher baseline associations experience greater amplifications in the outcome variable as the predictor increases. Such differences in exponential trajectories are visible in Figures 2, 3, and 5, which display the upper and lower bounds of the effects. These findings support the notion of sensitive dependence of initial conditions on the amplification of one's inherent level of association between rumination and negative emotion, as well as the notion that impulsive behavior may serve as an attractor state toward which those with stronger associations are drawn as rumination and negative emotion increase. These findings also support the

Emotional Cascade Model notion that, when an individual is in the midst of an emotional cascade, he or she may be at peak risk for engaging in impulsive behaviors in an attempt to distract from and short-circuit the feedback loop between rumination and negative emotion.

We also found evidence for a synergistic effect between rumination and negative emotion in impulsive people, where higher levels of both predicted higher elevated subsequent negative emotion and rumination. Similar synergistic effects were found in predicting subsequent impulsive behaviors. This demonstrates that high levels of both rumination and negative emotion lead to worse subsequent outcomes than if just one was elevated. For example, rumination without negative emotion may better characterize problem solving or reflection rather an emotional cascade (Treynor, Gonzalez, & Nolen-Hoeksema, 2003). Similarly, elevated negative emotion in the absence of rumination may subside more quickly.

This study also has relevance to the broader field of rumination, as our findings replicate previous research that has demonstrated the bidirectional effects of rumination and negative emotion (Moberly & Watkins, 2008). Furthermore, we found that rumination in the morning was a significant predictor of rumination multiple assessments later, indicating a predictive association ranging from six to nine hours. This finding supports the original conceptualization of rumination as a perseverative process over time (Nolen-Hoeksema, 1991), a finding that has not yet been demonstrated using experience sampling methodology. Additionally, in examining cross-level interactions across multiple analyses, we found evidence that women and those with BPD reporting elevations in one predictor had significantly higher elevations in the subsequent outcome. However, those with depression did not. Accordingly, bidirectional effects may be stronger in women, and BPD may be a disorder characterized as the extreme end of a continuum of emotional cascades and impulsivity. In contrast, rumination in the context of depression in impulsive individuals may not have stronger effects on increasing negative emotion, though there may have been low power for detecting a depression effect. It is also interesting to note that there was a significant effect of time in the study, such that scores on rumination and negative emotion decreased during the course of monitoring. These effects were unlikely due to decreases in compliance, which was very good in this study. Alternatively, there may have been potential therapeutic reactivity to self-monitoring such that monitoring of negative emotion and thought patterns help people better understand and respond to these experiences (Frederiksen, 1975). Alternatively, these effects may have simply been regression to the mean. Accordingly, potential therapeutic effects to self-monitoring should be further examined in future research.

The current study should be viewed in light of relevant limitations. First, few studies have examined rumination using momentary assessments. Accordingly, it can be difficult to operationalize rumination as a state experience rather than a general trait tendency. In the current study, we asked participants to rate their current thought patterns and how much they were focusing on upsetting situations. Because we did not ask participants if they were focused on the same thoughts as at a previous recording, it is difficult to determine if rumination, as we measured it, persisted across assessments. Furthermore, our rumination measure demonstrated lower within-person stability than did the measure used by Moberly & Watkins (2008). It is possible that we measured levels of intermittent upsetting thoughts at

each assessment, rather than rumination. Given that we found significant associations in rumination levels across an extended length of time, however, it seems likely that our measurement of rumination tapped persistent and repetitive negative thoughts to at least some extent. Another limitation was that this study was designed primarily to investigate impulsive behaviors, and accordingly all participants were required to report some degree of impulsivity to be included in the study. As such, it is possible that our findings on the nature of rumination may not generalize to non-clinical samples or clinical samples of primarily depressed individuals. Future studies should replicate the analyses of this study by including a control group and larger, more heterogeneous samples. There were also some limitations with some of our measurements of constructs, including using worry as an item for negative emotion and including future-oriented thinking as a form of rumination; however, these inclusions did not overly influence our results. Finally, we cannot definitely determine whether the effects identified were causal in nature and if impulsive behavior actually diminished emotional cascades.

The findings of the current study help to clarify the nature of the relationship between rumination and negative emotion in impulsive people, and signal a number of future directions. Future studies should examine the experience of rumination in greater depth, particularly the nature of the curvilinear relationships (e.g. exponential vs quadratic), the cognitive content of rumination, as well as if different types of rumination (e.g., past, current, future focus) interact differently with various emotions (e.g., anger, sadness, etc.). It may also be that rapid rumination has the strongest impact on negative emotion, as findings from other studies suggest that speed of thought increases the intensity of emotion experienced (Pronin, Jacobs, & Wegner, 2008).

Finally, our results indicated that the strength of the relationship between rumination and negative emotion may differ between people, and further research should examine factors that may explain why some people are particularly susceptible to the amplifying cycle of rumination and negative emotion. Such studies should examine the bidirectional effects of rumination and negative emotion over multiple time points using structural equation modeling and growth curve modeling. Finally, further research should examine theoretical and empirical distinctions between traditional conceptualizations of rumination and the emotional cascade model to determine the degrees of uniqueness and similarity between the models.

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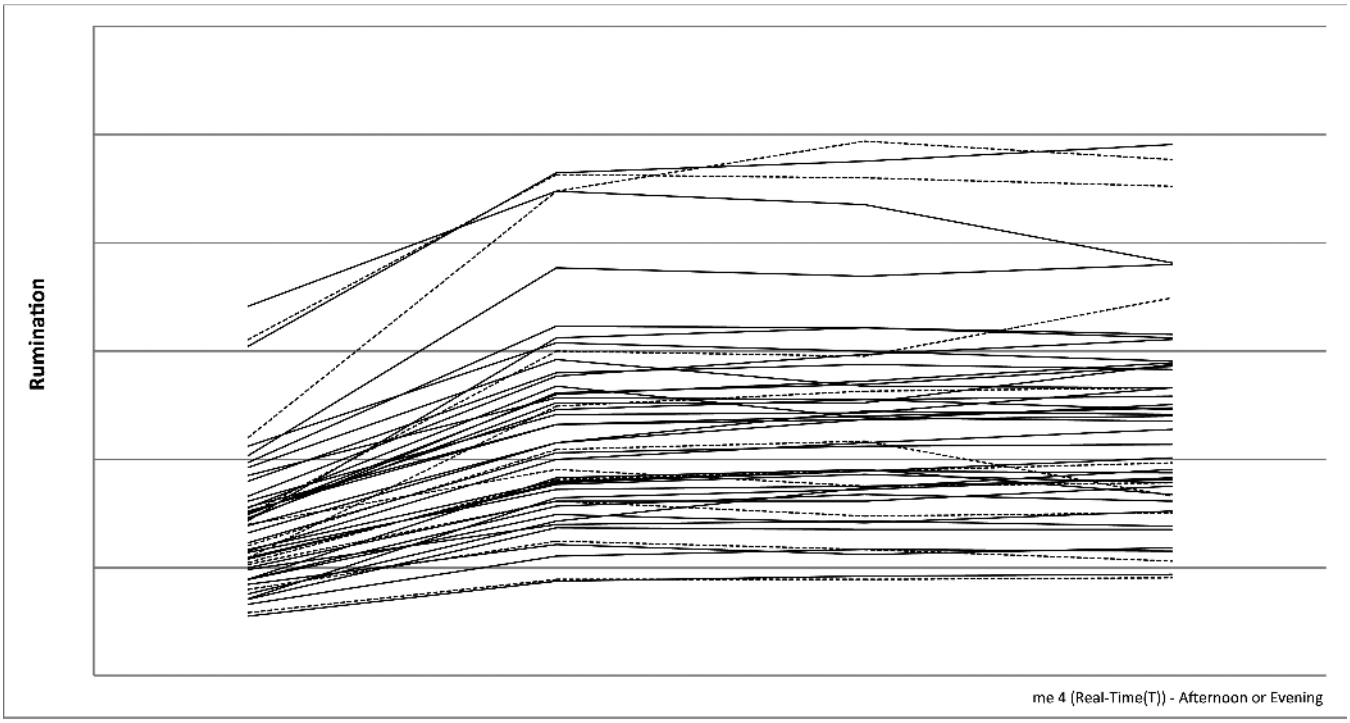
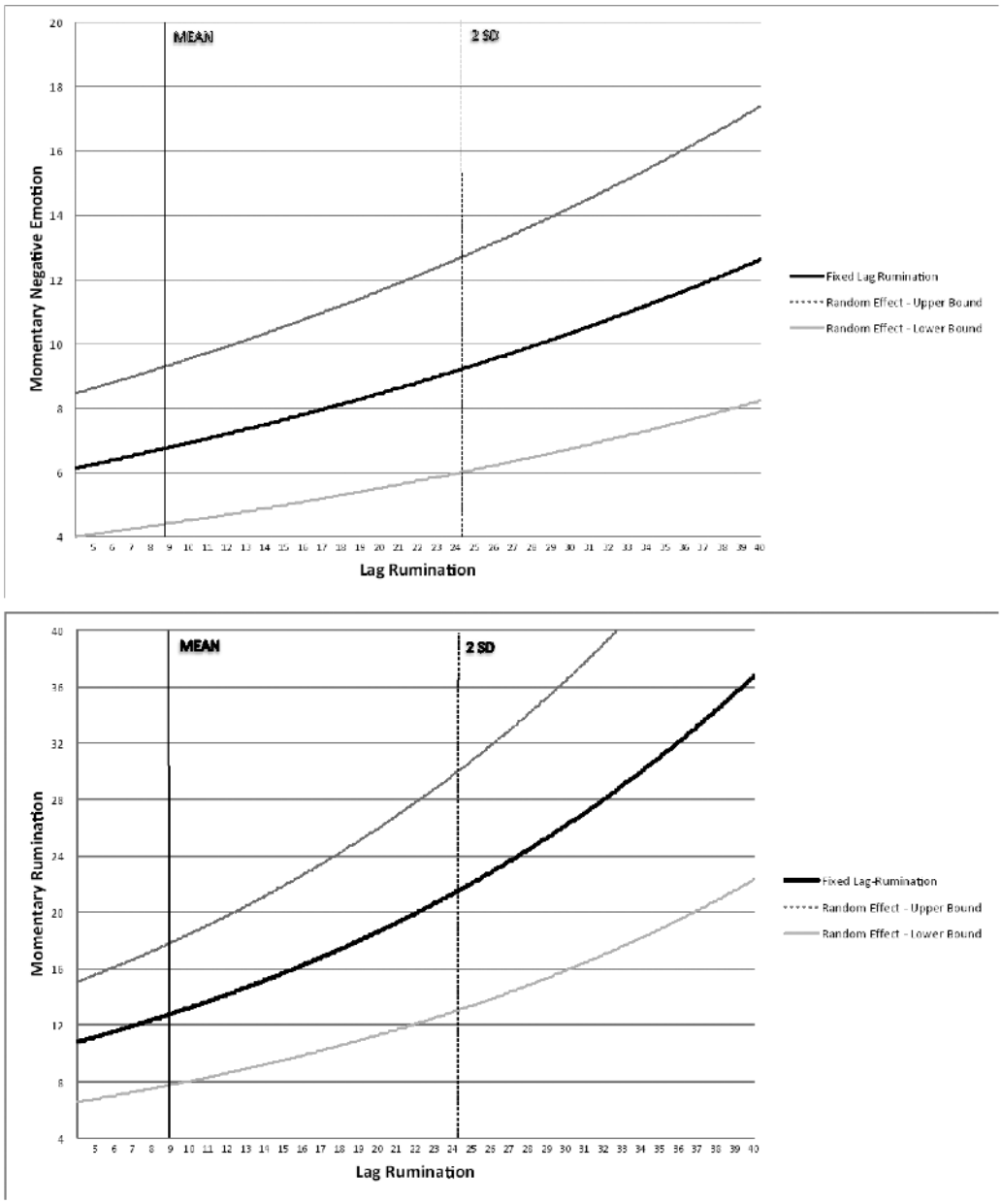


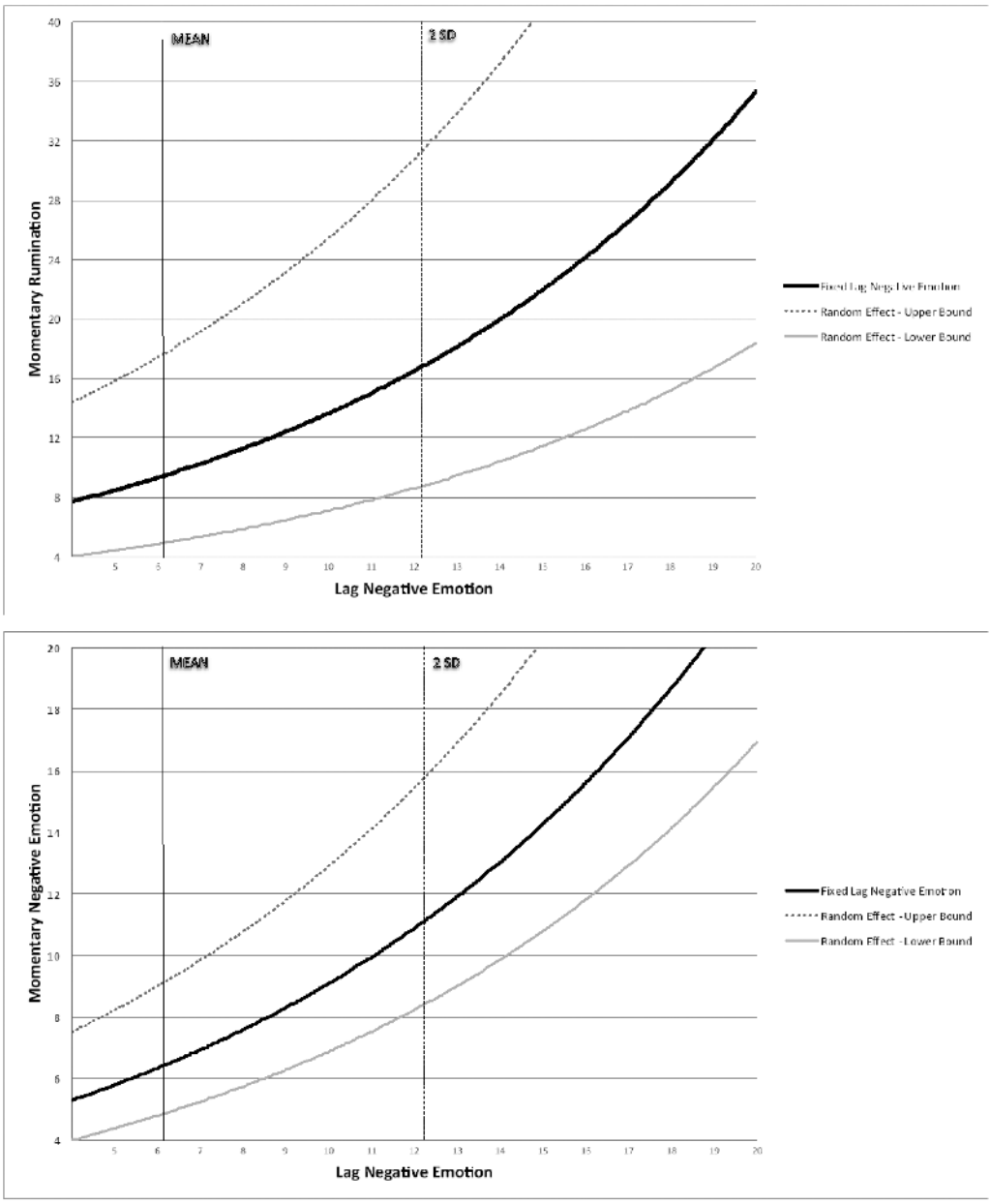
Note: Average rumination levels for each participant across four assessments. Average levels were generated by calculating each participant's average level for each of the lag rumination variables generated; Lag(T-N) indicates that the lag rumination variable was either 1, 2, or 3 observations prior to the current level of rumination (measured in the afternoon or evening). All lines represent one participant's scores, solid and dashed lines are presented for ease of interpretation.

Figure 1.
Persistence of Rumination Levels Over Four Observations with Approximately 7-9 Hours Between Assessments



The dark line indicates the fixed effect, and the gray lines represent the upper- and lower-boundaries arising from the random intercept, highlighting different trajectories between-persons.

Figure 2.
Lag Rumination Predicting Current Levels of Negative Emotion and Rumination



Note: The dark line indicates the fixed effect, and the gray lines represent the upper- and lower-boundaries arising from the random intercept, highlighting different trajectories between-persons.

Figure 3.
Lag Negative Emotion Predicting Current Levels of Rumination and Negative Emotion

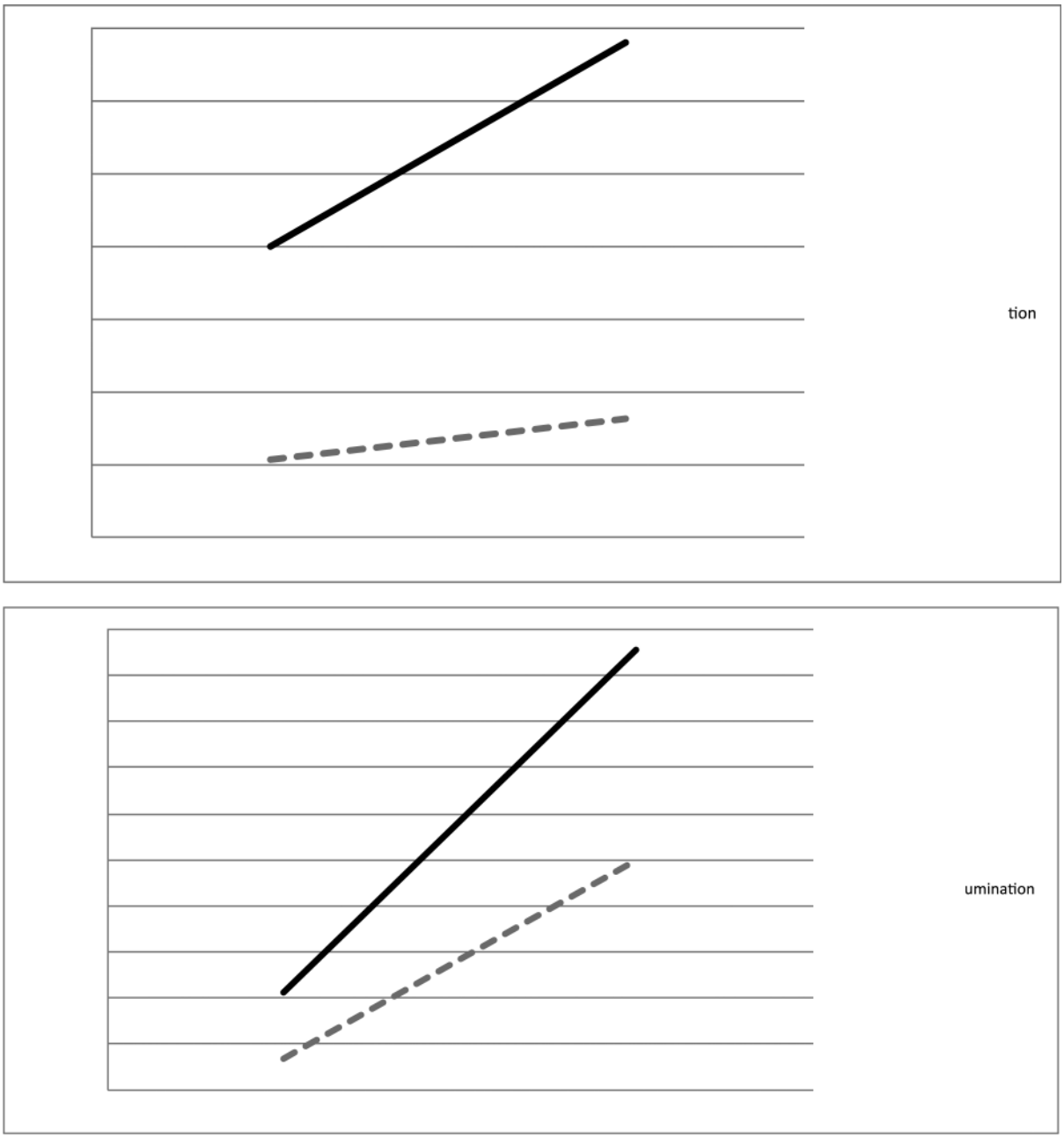
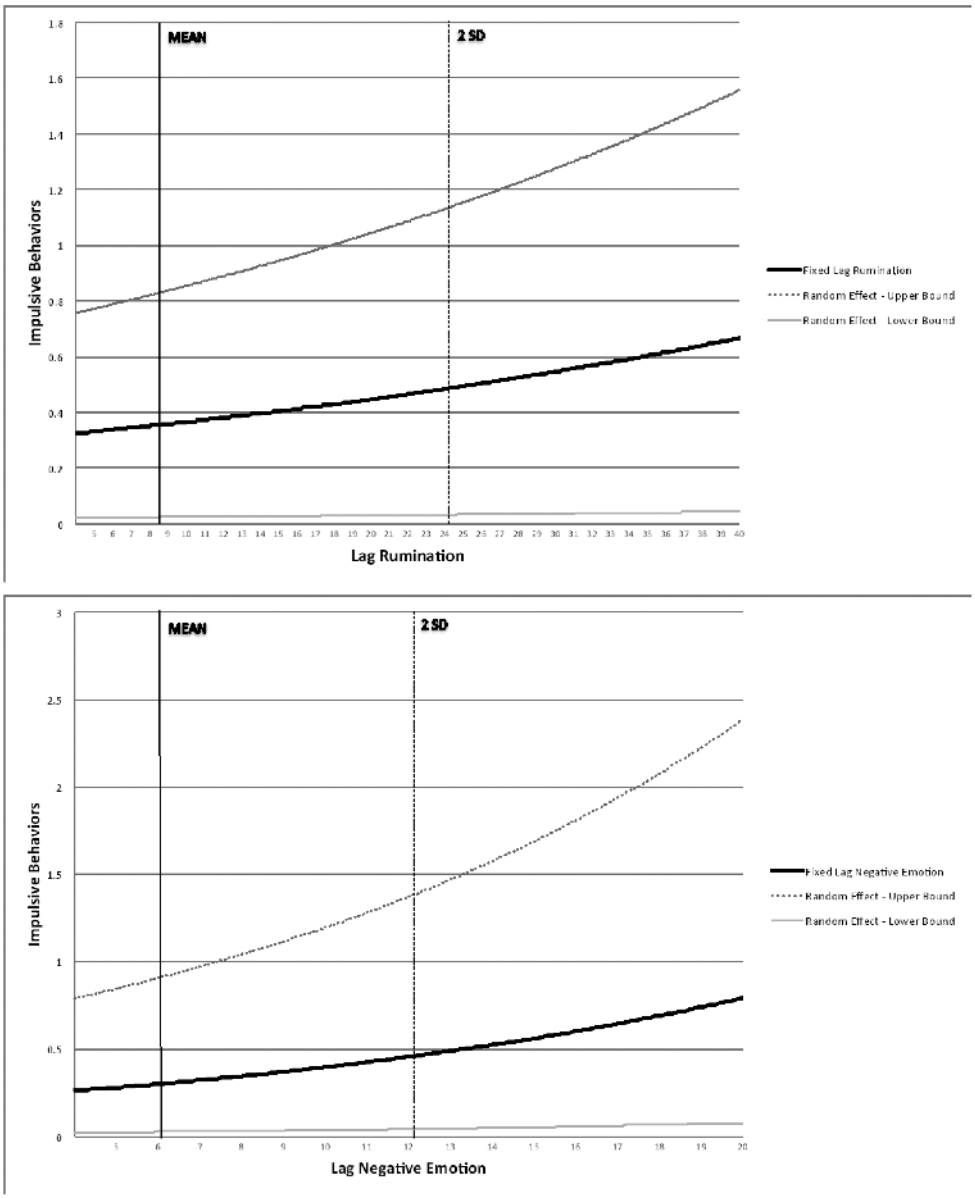
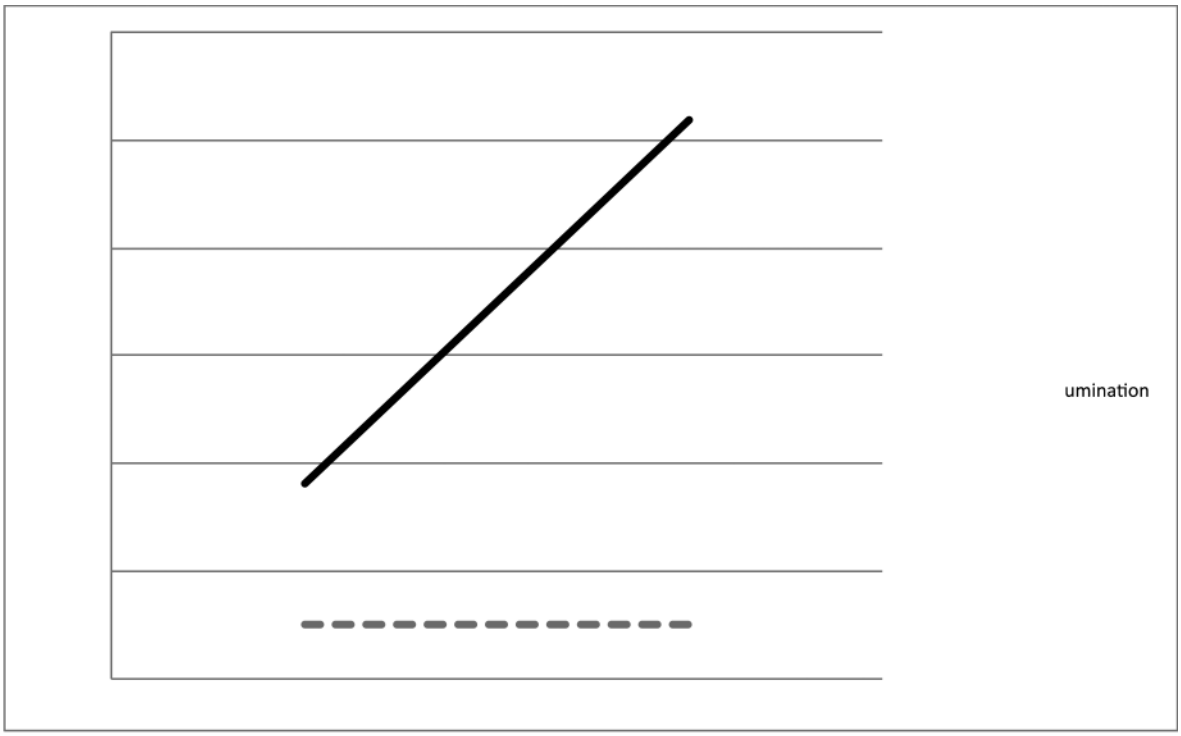


Figure 4.
Synergistic Effects between Lag Rumination and Lag Negative Emotion on Each Other



Note: The dark line indicates the fixed effect, and the gray lines represent the upper- and lower-boundaries arising from the random intercept, highlighting different trajectories between-persons.

Figure 5.
Lag Rumination and Negative Emotion Predicting Current Impulsive Behaviors



Note: High and low values indicate two standard deviations above or below the mean.

Figure 6.
Synergistic Effects between Lag Rumination and Lag Negative Emotion on Impulsive Behaviors