Affective dynamics in bipolar spectrum psychopathology: Modeling inertia, reactivity, variability, and instability in daily life

By: Sarah H. Sperry and Thomas R. Kwapil

Sperry, S.H., & Kwapil, T.R. (2019). Affective dynamics in bipolar spectrum psychopathology: Modeling inertia, reactivity, variability, and instability in daily life. *Journal of Affective Disorders, 251,* 195-204. https://doi.org/10.1016/j.jad.2019.01.053

Abstract:

Background: Bipolar psychopathology is characterized by affective dysregulation independent of mood episodes. However, previous research has relied on laboratory-based emotion-eliciting tasks or retrospective questionnaires that do not take into account temporal dynamics of affect. Thus, the present study examined affective dynamics (reactivity, variability, instability, and inertia) of low and high arousal negative affect (NA) and positive affect (PA) in daily life in those at risk for bipolar psychopathology. **Methods:** Undergraduates ($n = 135$) completed the Hypomanic Personality Scale and experience sampling surveys assessing affective experiences 8 times daily for 7 days. **Results:** HPS scores were associated with greater reactivity of NA when experiencing negative or stressful events, variability of NA (high and low arousal) and PA (high arousal), and instability of NA and PA (high and low arousal) in daily life. HPS scores were associated with a high probability of acute increases in NA and PA and were unassociated with levels of inertia. **Limitations:** This study only examined short-term dynamics over 7 days. Future studies should model both short- and long-term dynamics and whether these dynamics predict behavioral outcomes. **Conclusions:** These results provide evidence that bipolar spectrum psychopathology is characterized by reactivity of NA as well as variability, instability, and acute increases in NA and PA in daily life over-and-above mean levels of affect. Modeling affective dynamics may provide context-relevant information about the course and trajectory of bipolar spectrum psychopathology and should facilitate the use of experience sampling methodology to study and intervene in mood lability in patients with bipolar disorders.

Keywords: Bipolar spectrum psychopathology | Emotion dynamics | Affective dynamics | MSSD | Intraindividual variability

Article:

1. Introduction

Bipolar disorders affect approximately 4% of the population (Merikangas et al., 2007) and account for more than 150 billion dollars in direct and indirect costs annually in the United States

(Dilsaver, 2011). Bipolar disorders are associated with severe role impairment, extensive use of health and social services (Merikangas et al., 2007), and premature mortality (Roshanaei-Moghaddam and Katon, 2009). In contrast to traditional categorical diagnoses, evidence suggests that up to 9% of the population experiences bipolar symptoms, including those that do not meet full diagnostic criteria yet result in impaired functioning and poor outcomes (Judd and Akiskal, 2003, Merikangas et al., 2007), increased risk for suicide (Angst, 1998), and heightened risk for developing bipolar disorders (Angst and Cassano, 2005). Longitudinal studies indicate that individuals experiencing subthreshold bipolar spectrum psychopathology, as measured by the Hypomanic Personality Scale (HPS; Eckblad and Chapman, 1986), experience elevated rates of hypomanic episodes and conversion to bipolar spectrum disorders (Kwapil et al., 2000, Walsh et al., 2015). Thus, current models conceptualize bipolar psychopathology as a spectrum of clinical and subclinical symptoms and impairment, rather than as categorical disorders.

1.1. Affective dysregulation in bipolar spectrum psychopathology

Bipolar spectrum psychopathology is characterized by disruptions in the experience of affect that, at the extreme, include episodes of depression or mania. At a more nuanced level, bipolar spectrum psychopathology is characterized by affective hyper-reactivity, difficulties in recovery (i.e., the ability to return to core affect following reactivity), and lability across emotion-eliciting tasks in the lab, self-report questionnaires, and daily life assessments. However, further examination is needed to determine the specific nature of these disruptions and the extent to which they are associated with subclinical bipolar spectrum psychopathology.

1.1.1. Affective reactivity

The exact nature of affective reactivity in bipolar spectrum psychopathology is not entirely clear. Evidence suggests that bipolar disorders are characterized by hyper-reactivity of positive affect (PA) during mania (Henry et al., 2003), during episodes and euthymia (Johnson, 2005), and in response to positive events (Cuellar et al., 2009). In contrast, others report that bipolar psychopathology is characterized by hyper-reactivity of negative affect (NA) in response to stressful events (Alloy et al., 2006, Myin-Germeys et al., 2003) and neutral situations (M'Bailara et al., 2009). Furthermore, others suggest that hyper-reactivity is only present in those with bipolar disorder with a history of depressive episodes (Henry et al., 2010). Lastly, there is contradictory evidence that bipolar spectrum psychopathology is associated with hyper-reactivity across levels of valence but only at high arousal levels (M'Bailara et al., 2009), whereas others report no differences in reactivity across arousal levels (Gruber et al., 2011). Thus, there is a need to clarify whether bipolar spectrum psychopathology is characterized by hyper-reactivity (in terms of valence and arousal) to positive or negative events and whether levels of hyper-reactivity are dependent on severity of bipolar spectrum psychopathology.

1.1.2. Affective recovery

Disruptions in affective recovery, or the ability to return to core affect following reactivity, have been implicated across the bipolar spectrum. Specifically, studies indicate that there is a tendency to dwell and persist on NA and PA in bipolar I disorder (Johnson et al., 2008), sustained change in affect following stressful daily events in cyclothymia (Goplerud and

Depue, 1985), and trouble returning to baseline affect especially in response to PA across the bipolar spectrum (Farmer et al., 2006). However, others indicate no differences in affective recovery between those with bipolar I disorder and healthy comparison subjects (Gruber et al., 2011).

1.1.3. Affective lability

Affective lability (also referred to as variability) is consistently implicated in bipolar psychopathology. Bipolar I disorder is associated with increased variability of NA (Johnson et al., 2016), increased variability of NA and PA during episodes and euthymia (Henry et al., 2008), and biphasic shifts between NA and PA (Henry et al., 2001, Reich et al., 2012). Furthermore, people with subclinical bipolar symptoms experience elevated affective variability (Angst et al., 2003, Hofmann and Meyer, 2006, Lovejoy and Steuerwald, 1995). Affective variability predicts poorer functioning and development of bipolar spectrum disorders (Angst et al., 2003, Henry et al., 2008) and conversion to bipolar spectrum disorders via person-level risk calculators (Hafeman et al., 2017). Two studies using relaxation oscillator frameworks found that in terms of self-reported depression, those with “unstable” bipolar disorder have non-linear time-series, suggesting high levels of affective variability over time (Bonsall et al., 2015, Bonsall et al., 2012). Although bipolar spectrum psychopathology generally involves affective lability, characteristics of instability in daily life are not clear. For example, it is unclear whether those on the bipolar spectrum experience frequent changes in affect, infrequent but large changes in affect, or whether they experience variability of NA or PA or biphasic shifts between the two.

1.2. Limitations of the previous literature

Contradictory findings regarding the experience of affect in bipolar spectrum psychopathology likely result from traditional methods of measuring the experience of affect. First, there has been an over-reliance on using emotion-eliciting paradigms to induce mood in the laboratory. Although informative, these laboratory manipulations are not well correlated with the experience of affect in daily life (Koval et al., 2015), may not fully capture the dynamics or salience of real-world affective processing (Schimmack, 2003), and differ in time-scale of the measurement of affect (Johnson et al., 2016). Second, there is evidence that, at the trait level, individuals experiencing subclinical and clinical manifestations of bipolar psychopathology display inter-episodic affective lability (Hofmann and Meyer, 2006, Lovejoy and Steuerwald, 1995) that predicts impaired functioning and symptoms (Henry et al., 2008, Henry et al., 2001). Despite this, research has concentrated on understanding episode-dependent lability. Third, prior work is limited by traditional views of affective science that specifically study means levels of affect by focusing on the experience of affect as a state rather than a dynamic phenomenon (Kuppens et al., 2009, Scherer, 2000). Although traditional emotion research suggests that people can be meaningfully characterized by mean levels of affect (Watson and Tellegen, 1985), modern theories contend that examining variability of affect provides context-relevant information and may be an important individual difference variable in psychopathology research (Jahng et al., 2008, Kuppens et al., 2010b).

1.3. Measurement and modeling of affective dynamics

The measurement and modeling of affective dynamics in daily life provides a powerful method for addressing the aforementioned limitations and provides a conceptual and methodological framework for understanding affective experiences. However, limited research has modeled affective dynamics in bipolar spectrum psychopathology (Ebner-Priemer and Trull, 2009). Affective dynamics reflect time-dependent fluctuations in affect (Kuppens et al., 2010a) and provide information about affective functioning over-and-above state or trait levels of affect (Eaton and Funder, 2001, Kuppens et al., 2012, Kuppens et al., 2007, Penner et al., 1994, van de Leemput et al., 2014). Affective dynamics are best modeled from time-series data collected via experience sampling methodology (ESM), a daily diary method that repeatedly assesses affect and experiences across time (Jahng et al., 2008, Trull et al., 2015). ESM offers the advantages of enhanced ecological validity by assessing individuals in their real-world environments, minimizing retrospective bias by assessing experiences in the moment, and allowing examination of the effects of context (Mehl and Conner, 2012, Oorschot et al., 2009). Although several affective dynamics can be modeled from time-series data, the most consistently assessed in personality and psychopathology are reactivity, inertia, variability, and instability, which provide coverage of affective reactivity, recovery, and lability in daily life.

Affective dynamics have been proposed to reflect several important theoretical assumptions regarding the fluctuations of affect in daily life (see Kuppens, 2015 for review). Specifically, Carver (2015) proposes that affective dynamics, namely instability and variability, result from approach and avoidance behaviors as a result of goal attainment. In contrast, Hollenstein (2015) argues that dynamics are a proxy for regulatory flexibility, or the extent to which an individual flexibly adjusts their affect from their “core affect” to an “attractor state” in response to internal or external environmental changes. However, the present study conceptualized affective dynamics based on the *DynAffect Model* proposed by Kuppens et al. (2010a). The DynAffect Model proposes that each individual has a “home-base” or core affect that involves both valence and arousal. When an individual experiences an event in daily life, they move away from their core affect and their ability to return is dependent on regulatory flexibility and concurrent external and internal influences over time. Affective reactivity, inertia, variability, and instability are temporal dynamics relevant to the bipolar spectrum that map onto the *DynAffect Model* and are measureable in the laboratory and in daily life.

In terms of affective reactivity, previous studies examined whether participants report more intense NA or PA following stressful/unpleasant/pleasant events (e.g., Myin-Germeys et al., 2003). Some have argued that examining reactivity requires event-contingent sampling; however, Scollon et al. (2009) note that event-contingent sampling may influence people to highlight non-important events and produce behavioral change. Thus, random time-sampling and assessing reactivity on a moment-to-moment basis is recommended (Myin-Germeys et al., 2003, Scollon et al., 2009). Measuring affective reactivity in this manner addresses the limitations of laboratory-based studies by examining reactivity in response to multiple experiences, across levels of arousal and valence, and across time and contexts.

ESM lends itself to the study of affective inertia, which is characterized by persistence of affective states or resistance to change (Koval et al., 2015, Kuppens et al., 2010a, Thompson et al., 2012). Inertia is an affective dynamic that reflects the lack of affective recovery in bipolar spectrum psychopathology by capturing the extent to which affect is correlated over time using autocorrelation or autoregressive slope models. Thus, if individuals on the bipolar spectrum display poor affective recovery, they should have a high autocorrelation of NA or PA over time.

Affective lability can be assessed via several affective dynamics, each of which provides relatively unique information about the fluctuations of affect in daily life. The most commonly used measures include within-person variance (WPV), a measure of affective variability; mean square of successive differences (MSSD), a measure of affective instability; and probability of acute change (PAC), a measure of acute increases or decreases in affect (Ebner-Priemer and Trull, 2012, Jahng et al., 2008). WPV reflects the extent to which an individual's affect deviates from their mean levels using the standard deviation of their affect ratings (amplitude of affect ratings; Eid and Diener, 1999). However, WPV does not account for variability across time (Ebner-Priemer and Trull, 2009, Jahng et al., 2008). MSSD measures both fluctuations in affect (amplitude of affect ratings), but also temporal dependency (frequency and serial ordering; Ebner-Priemer and Trull, 2012, Ebner-Priemer and Trull, 2009, Jahng et al., 2008). WPV and MSSD are both insensitive to the degree to which changes in affect from one moment to the next are statistically meaningful or directional. PAC indices examine whether instability is characterized by meaningful, dramatic, or statistically significant changes in affect in a particular direction (Jahng et al., 2008).

1.4. Goals and hypotheses

This is the first study to our knowledge to model short-term affective dynamics to understand the affective experiences of people at risk for bipolar spectrum disorders. Studying affective dynamics in a non-clinical sample enables the examination of affective functioning across a continuum of presentations without the confounds of disease burden, medication, or episode-dependent differences. The study examined the associations of bipolar spectrum psychopathology, as measured by HPS scores, with the experience of affect and contextual experiences in daily life. Based on previous studies (e.g., Kwapil et al., 2011, Walsh et al., 2012, Sperry and Kwapil, 2017), it was expected that HPS scores would be associated with elevated high and low arousal NA and high arousal PA, subjective reports of affective lability, and stressful experiences. It was expected that HPS scores would also be associated with affective hyper-reactivity across both positive and negative events. Specifically, we predicted that HPS scores would be associated with hyper-reactivity of NA following stressful/negative experiences and hyper-reactivity of PA following positive experiences. We predicted that HPS scores would be associated with variability and instability (indicated by higher WPV, MSSD, and low autocorrelation) of NA and PA in daily life; however, a priori hypotheses were not made regarding levels of the arousal of affect, given the lack of previous findings in this area. Furthermore, we predicted that HPS scores would be associated with a higher probability of large or acute increases (PAC) in NA and PA. Lastly, we predicted that these findings would hold after accounting for mean levels of NA and PA.

2. Methods

2.1. Participants

Non-clinically ascertained young adults (*n* = 147) enrolled in the study via an online course-credit portal for students in general psychology courses. Usable data were available for 135 participants. Participants were dropped due to invalid questionnaires (*n* = 4), completing less than 15 ESM protocols (*n* = 5), and variance of their ESM response less than -1.75 SD below the mean (*n* = 3) indicating invalid ESM responding. Demographic characteristics and HPS scores for the full and final samples did not differ (Table 1). The final sample was representative of the racial and ethnic background of the psychology department at the host university as well as other large public universities in the United States. Eleven percent of the sample (*n* = 15) scored at least 1.5 standard deviations above the mean on the HPS. Note that this sample was used by Sperry and Kwapil (2018); however, they did not investigate hypotheses regarding bipolar spectrum psychopathology. This study was approved by the UIUC IRB and participants provided informed consent.

Table 1. Demographic characteristics of included and dropped participants.

Sample characteristic	Included ($n = 135$)	Dropped ($n = 12$)	Test statistic	p value
HPS total	18.44 (8.09)	19.92 (8.96)	$t\,(145) = -0.60$	.55
Age	19.31 (1.15)	19.17 (1.27)	$t\,(145) = 0.41$	.68
Race/ethnicity				
African American	10%	8%	$X^2(4) = 2.39$	.66
Asian	29%	50%		
White	46%	33%		
Hispanic/Latino	14%	8%		
Native American	0%	0%		
Other	1%	0%		
Sex				
Female	59%	58%	$X^2(1) = 0.00$	.99
Male	41%	42%		

2.2. Materials

Participants completed demographic questions, the HPS, and an infrequency scale to detect invalid responders. The HPS assesses bipolar psychopathology and risk for developing bipolar spectrum disorders. The scale consists of 48 true-false items with good internal consistency (coefficient alpha = 0.87) and test-retest reliability (*r* = 0.81; Eckblad and Chapman, 1986). The HPS was intermixed with a 13-item infrequency scale (Chapman and Chapman, 1983). Participants who endorsed more than two infrequency items were dropped.

The ESM protocol included items that assessed high and low arousal NA and PA, subjective affective lability ("Right now my emotions feel out of control", "Since the last beep my mood was going up and down"), as well as negative/positive events ("The most important event since the last beep was negative/positive"), stressful situations ("Right now my situation is stressful"), and feelings of success ("I am successful in my current activity"). Affect items were selected from the Positive and Negative Affect Schedule (Watson et al., 1988) and validated ESM questionnaires (Kwapil et al., 2011, Sperry and Kwapil, 2017, Walsh et al., 2012) to cover the full affective circumplex (Russell, 1980). All items were answered on a 7-point scale ranging from "1. Not at all" to "7. Very much." Indices were created for high arousal NA (nervous, angry, afraid, irritable), low arousal NA (sad, bored, sluggish), high arousal PA (energetic, enthusiastic), and low arousal PA (relaxed, satisfied, calm). Items were delivered via the smartphone application Metricwire (Trafford, 2015). Note that there was no within-survey missingness as Metricwire only saves and uploads completed surveys.

2.3. Procedures

Participants attended an information session during which they downloaded Metricwire on their smartphone, completed self-report questionnaires, were trained on ESM procedures, and completed a practice ESM survey that was not included in the final data. Participants were notified to complete ESM surveys 8 times daily between noon and midnight for seven and a half days at stratified random intervals (randomized within eight, 90-minute blocks). Participants had five minutes to respond, after which the ESM survey was no longer available. Participants came to the lab once during the week to encourage adequate responding.

2.4. Statistical analyses and power

ESM data have a hierarchical structure in which ratings in daily life (level 1) are nested within participants (level 2). Multilevel modeling is recommended for ESM data as it provides a more appropriate method for analyzing nested data than conventional unilevel analyses (Nezlek, 2012). Level 1 predictors were group mean centered and level 2 predictors were grand mean centered. Associations between HPS scores and daily affective experiences were measured by assessing the direct effects between the level 2 predictor (HPS) and level 1 criteria (ESM ratings).

Affective dynamics were calculated via the following methods and formulas. Using linear regression, we examined the association of HPS scores with inertia, variability, instability, and probability of acute change at step 1 of the regression analyses, followed by examining the associations with HPS over-and-above mean levels of NA and PA at step 2. Analyses computed in Mplus 8 used Maximum Likelihood Estimation with Robust Standard Errors (MLR) which can handle missing and non-normal data (Muthén & Muthén, 1998–2010). Importantly, data from the first ESM protocol of each day was removed so that dynamics did not assess successive differences between the last protocol of the prior day and the first protocol of the following day. In instances of missing data, successive differences are not calculated and are viewed as missing.

2.4.1. Affective reactivity

To examine affective reactivity, cross-level interactions, or slopes-as-outcomes, we tested whether the level 2 predictor (HPS score) was associated with the slope of the level 1 predictors (emotion-eliciting experience) and criteria. For example, we tested whether HPS scores predicted the association of experiencing a stressful event and NA in the moment.

2.4.2. Affective inertia

Autocorrelation is used to assess affective inertia (Jahng et al., 2008, Kuppens et al., 2010a). Autocorrelation coefficients, or ACORR(*h*), in which *h* represents the time lag between signals, were computed with a lag of one (e.g., examining the extent to which high arousal NA at time t is correlated with high arousal NA at time $t + 1$). Best practices involve removing linear trends in the data before estimating ACORR(*h)* values, as underlying trends may produce biased autocorrelations (Jahng et al., 2008). In order to detrend the data, linear slopes were fitted to each participant separately for high and low arousal NA and PA. Unstandardized residuals were saved, which removed the linear trend between Affect_t and Affect_{t+1}. ACORR(1) coefficients were then calculated for each participant. High values of ACORR represent resistance to change or inertia (high temporal dependency), whereas low scores indicate low temporal dependency.

2.4.3. Affective variability and instability

Multiple methods were employed to examine affective variability and instability. WPV involves computing the standard deviation of each participant's high and low arousal PA and NA ratings (Eid and Diener, 1999, Jahng et al., 2008). Three steps were taken to compute MSSD. First, lag 1 variables were created for high and low arousal NA and PA as well as time (in seconds) between ESM questionnaires. Second, we calculated the square of successive differences (SSD) of each daily affect category, which examined the squared differences between affect at time_i and time_{i+1}. SSD assumes that the occasions are equally spaced in time such that $\text{time}_i - \text{time}_{i+1}$ is the same for each *i,* where time_i is the time at occasion *i* (Jahng et al., 2008). However, ESM administers surveys at randomized times that vary across individuals. Based on Jahng et al. (2008), we adjusted SSDs to create adjusted square of successive differences (ASSD) by dividing each SSD by $[(t_{i+1} - t_i)/Mdn(t_{i+1} - t_i)]^{\lambda}$ where $Mdn(t_{i+1} - t_i)$ is the median of the time intervals for each *i* for each participant. Lambda (λ) was chosen to make the differences between each successive difference as constant as possible. Then, ASSD's were used in the equation for calculating MSSD for each participant. Higher MSSD values represent more affective instability within days.

In order to calculate acute change in affect, we computed PAC for each participant. PAC is computed as the number of acute changes divided by the total changes across all ESM occasions (Jahng et al., 2008). PAC is calculated by first assessing whether adjusted successive differences (ASD) represent a meaningful increase. Researchers vary in determining what constitutes a "meaningful" increase in their sample, referred to as the acute cutoff (AC). Following Jahng et al. (2008) and Trull et al. (2008), we selected AC values of the 90th percentile. First, ASD's were standardized across the sample. All ASD's that fell in the range of the 90th percentile received an AC value of 1, all others were coded 0. PAC was computed by dividing the number of acute changes (AC values > 90th%), by the total number of ASD's for each participant respectively. Higher PAC scores represent higher levels of acute instability.

2.4.4. Power

Determination of power and sample sizes in multilevel designs is complicated because the design ostensibly has two sample sizes: the number of within-person observations and the number of between-person observations. Monte Carlo Simulation is the most appropriate method for determining power and sample size in multilevel data. Post-hoc power was computed via Monte Carlo Simulation based on recommendations by Heck and Thomas (2015). Using assumed population values (produced by saving model estimates based on 135 participants), entering all parameters, and specifying 500 replications, power was estimated at 0.80 for examining direct effects between level 2 and level 1 measures. Additionally, using 500 replications, power was estimated to be 0.69 for determining cross-level interactions.

3. Results

Participants completed an average of 39 usable ESM protocols (SD = 12, range = 15–60). HPS scores covered a wide range on the measure (M = 18.44, SD = 8.09, range = 2–43) consistent with other studies using the HPS with undergraduate students (e.g., Kwapil et al., 2011, Walsh et al., 2012, Walsh et al., 2015, Sperry et al., 2015, Sperry and Kwapil, 2017). Number of completed ESM surveys was unassociated with HPS scores (r = 0.01, p = .95) indicating that there were no systematic differences in amount of missing protocols between those who are high or low on the HPS. Descriptive statistics for ACORR, WPV, MSSD, PAC, and within and between-person correlations for the four affect domains are reported as supplemental material.

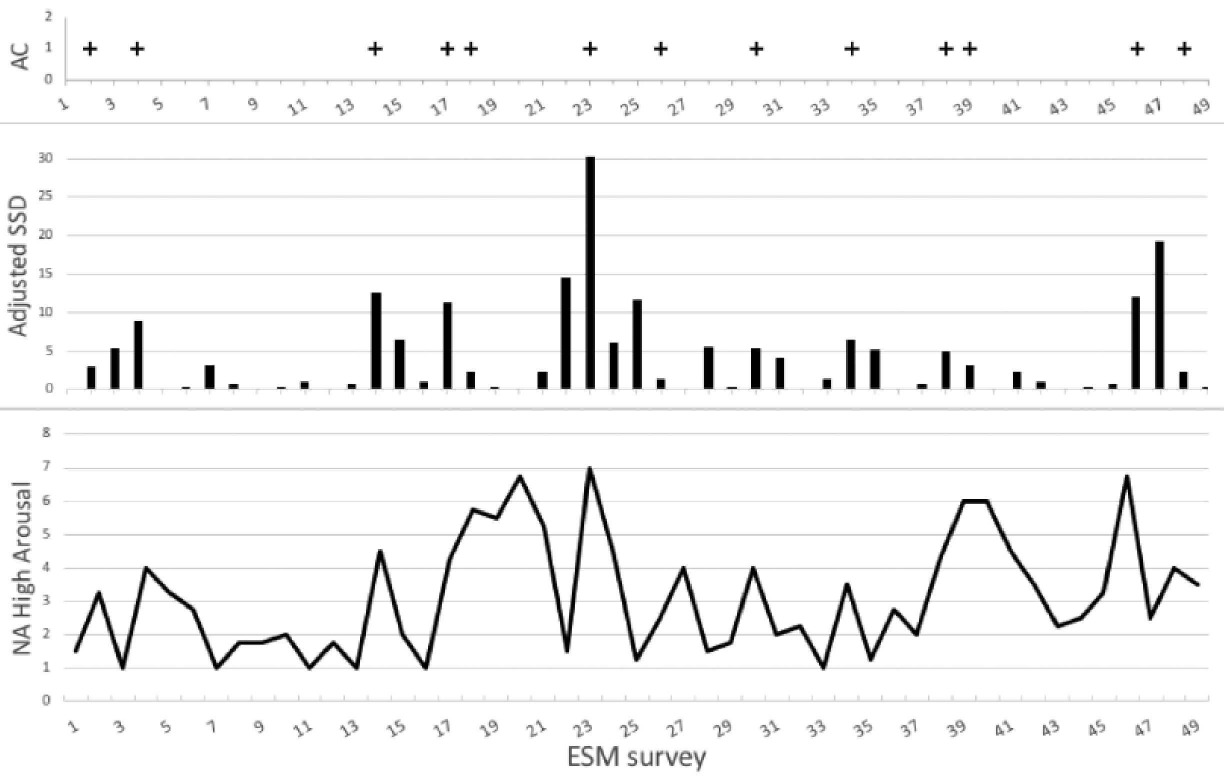

Fig. 1. Affective dynamics of participant A, a high scorer on the HPS

Daily state levels of NA high arousal are plotted on the bottom. In the middle, AASD's are plotted. At the top, + signs represent an acute change (AC > 1 SD). Participant A (HPS = 1 SD above mean) completed 49 ESM surveys and displayed high levels of instability in daily life: MSSD = 4.79, PAC = 0.27, WPV = 1.73, ACORR(1) = −0.06.

In order to visually display time-series data and different profiles of affective dynamics, one high scorer on the HPS and one low scorer are presented in Figs. 1 and 2. Participant A (Fig. 1) was characterized by elevated bipolar spectrum psychopathology (HPS = 1 SD above the mean) and heightened NA variability (WPV = 1.73), NA instability (MSSD = 4.79), probability of acute increases in NA (PAC = 0.27), and low levels of NA inertia (ACORR = −0.06). In contrast, participant B (Fig. 2) was characterized by low levels of bipolar spectrum psychopathology

(HPS = 1 SD below the mean) and minimal variability (WPV = 0.30), instability (MSSD = 0.09), probability of acute increases in NA (PAC = 0.02), and inertia (ACORR = 0.03).

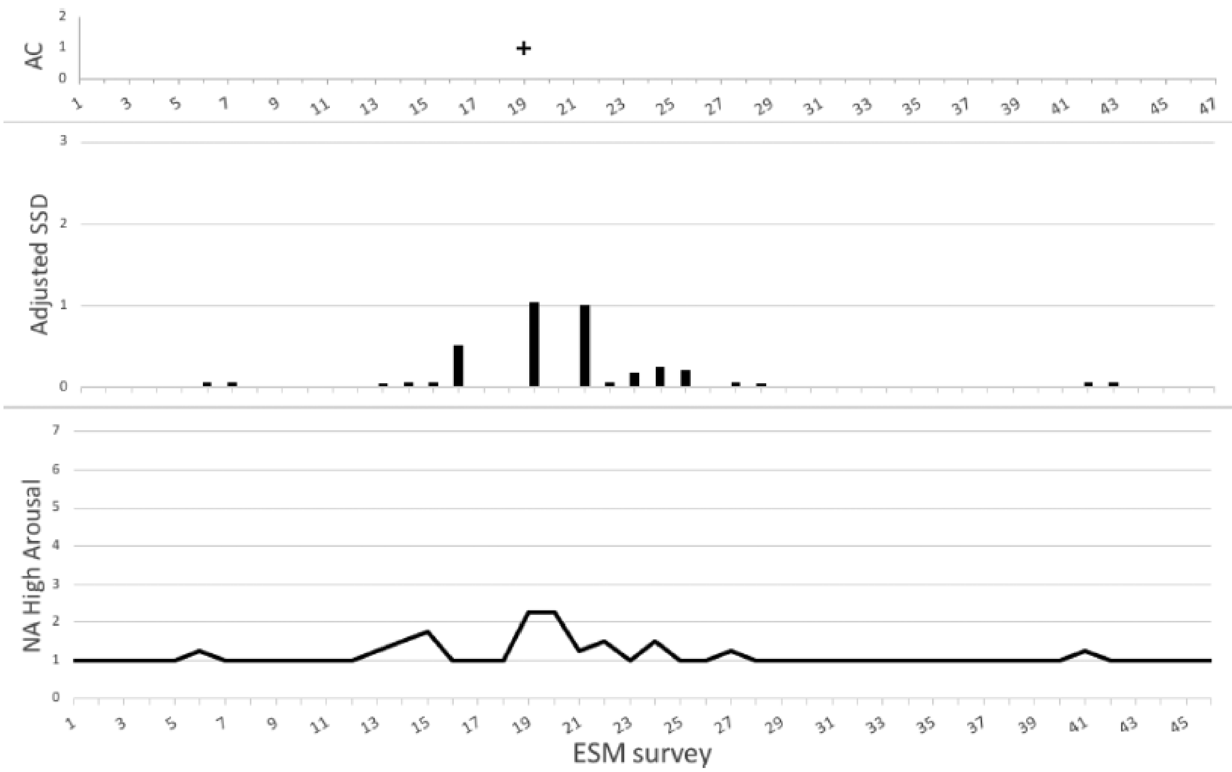

Fig. 2. Affective dynamics of participant B, a low scorer on the HPS
Daily state levels of NA high arousal are plotted on the bottom. In the middle, AASD's are plotted. At the top, + signs represent an acute change (AC > 1 SD). Participant B (HPS = 1 SD below the mean) completed 47 ESM surveys and displayed low levels of instability in daily life: MSSD = 0.09, PAC = 0.02, WPV = 0.30, ACORR(1) = 0.03.

Associations of bipolar spectrum psychopathology, as measured by the HPS, with affect and experiences in daily life are presented in Table 2. Elevated bipolar psychopathology was associated with both high and low arousal NA, feeling like one's emotions were out of control, and feeling like one's mood was going up and down. HPS scores were unassociated with PA in daily life. Consistent with previous studies (Kwapil et al., 2011, Sperry and Kwapil, 2017, Walsh et al., 2012), bipolar spectrum psychopathology was associated with reported negative and stressful situations, but not positive events.

Bipolar spectrum psychopathology was associated with hyper-reactivity of NA in daily life (see Table 3). Specifically, when experiencing an important negative event, participants were more likely to endorse high arousal NA; however, this was especially true for high scorers on the HPS compared to low scorers (see Fig. 3). Furthermore, when experiencing an important negative event or a stressful situation, high HPS scorers were more likely to report that their emotions felt out of control (see Fig. 4) and that their mood was going up and down. Contrary to expectation, HPS scores were unassociated with hyper-reactivity of PA when experiencing important positive/successful events.

Table 2. Association of HPS with affect, experiences, and behaviors in daily life.

Level 1 criterion	**Level 2 predictor** **γ_{10} (df = 133)** **HPS**
Affect	
NA high arousal	0.376 (0.074)***
NA low arousal	0.136 (0.056)*
PA high arousal	0.150 (0.086)
PA low arousal	−0.090 (0.076)
Emotions out of control	0.576 (0.098)***
Mood up and down	0.672 (0.104)***
Situation	
Current situation is stressful	0.476 (0.110)***
Experience positive	−0.047 (0.089)
Experience negative	0.240 (0.062)***
Behaviors & cognitions	
Successful in activity	0.094 (0.083)
Impulsivity	0.444 (0.068)***
Trouble concentrating	0.470 (0.102)***
Thoughts racing	0.675 (0.104)***
Doing many things	0.433 (0.088)***
Sense of self	
Feel confident	0.123 (0.095)
Feel uncertain	0.437 (0.104)***
Feel like the center of attention	0.351 (0.066)***

Raw multilevel regression coefficients indicating the relation of the level 2 predictor (HPS) and the level 1 (daily life experience) criteria with the standard error in parentheses.
* $p < .05$. ** $p < .01$. *** $p < .001$.

Table 3. Affective reactivity and bipolar spectrum psychopathology.

Level 1 criterion	**Level 1 predictor** **Y_{10} (df = 133)**		**Level 2 predictor** **HPS** **Y_{11} (df = 132)**
NA high arousal	Event negative	0.254 (0.012)***	0.026 (0.012)*
NA low arousal	Event negative	0.196 (0.014)***	0.006 (0.014)
Mood up and down	Event negative	0.239 (0.020)***	−0.023 (0.020)
Affect out of control	Event negative	0.212 (0.017)***	0.049 (0.016)**
NA high arousal	Situation stress	0.250 (0.013)***	0.010 (0.013)
NA low arousal	Situation stress	0.153 (0.013)***	0.004 (0.010)
Mood up and down	Situation stress	0.194 (0.017)***	0.038 (0.016)*
Affect out of control	Situation stress	0.198 (0.018)***	0.044 (0.018)*
PA high arousal	Event positive	0.295 (0.015)***	0.009 (0.015)
PA low arousal	Event positive	0.282 (0.013)***	0.001 (0.011)
PA high arousal	Successful	0.232 (0.019)***	0.012 (0.086)
PA low arousal	Successful	0.263 (0.015)***	−0.012 (0.014)

Raw multilevel regression coefficients indicate the relation of the level 2 predictor (HPS) and the slope between the level 1 predictor and criterion (ESM items). Standard errors are presented in parentheses.
* $p < .05$. ** $p < .01$. *** $p < .001$.

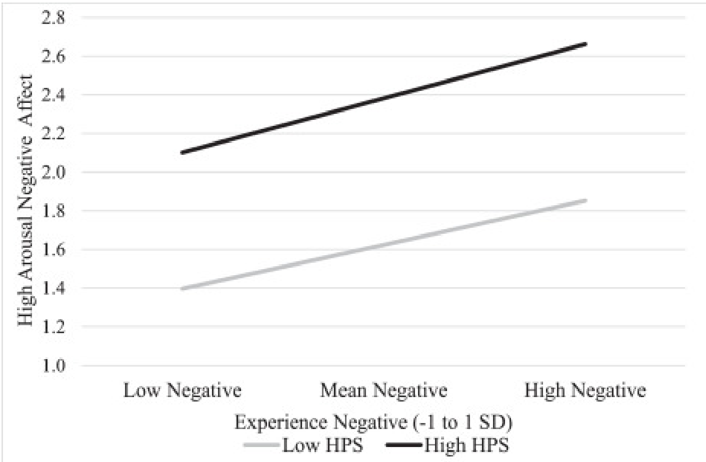

Fig. 3. Hyper-reactivity of NA during negative experiences.

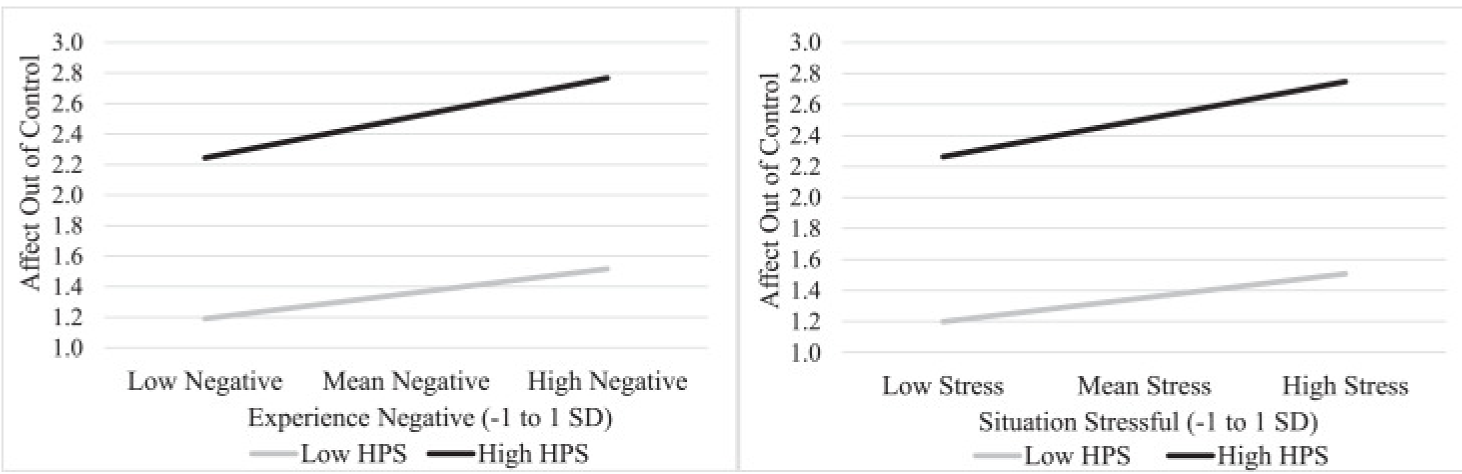

Fig. 4. Affect out of control during negative and stressful experiences.

Associations between each affective dynamic and bipolar spectrum psychopathology are presented in Table 4. HPS scores were associated with variability (WPV) of high and low arousal NA and high arousal PA, instability (MSSD) of high and low arousal NA and PA, and probability of acute increases in high and low arousal NA and PA in daily life. HPS scores were negatively associated with inertia (ACORR) of high arousal NA. All analyses remained significant after accounting for mean levels of high and low arousal NA and PA in daily life with the exception of the negative association between ACORR(1) of high arousal NA and the HPS.

4. Discussion

The present study examined the extent to which bipolar spectrum psychopathology was associated with affective reactivity, variability, instability, and inertia in daily life across levels of affective valence and arousal. This was the first study to our knowledge to apply modern theories and measurement of affective dynamics in bipolar psychopathology. Findings suggested that bipolar spectrum psychopathology, even in a non-clinically ascertained sample, was associated with reactivity of NA as well as variability and instability of NA and PA in daily life, over-and-above mean levels of affect. Furthermore, this study demonstrated the feasibility and importance of assessing multiple indices of affective dynamics in daily life using ESM.

Table 4. Association of affective dynamics and bipolar spectrum psychopathology.

Affective dynamic	**Step 1** HPS (df = 133)	**Step 2** HPS (df = 132)	**Mean affect** (df = 132)	**Total R^2**
Within-person variance				
High arousal NA	0.46***	0.20**	0.58***	0.48
Low arousal NA	0.23**	0.16*	0.37***	0.18
High arousal PA	0.24**	0.22*	0.12	0.07
Low arousal PA	0.14	0.14	0.01	0.02
Mean square of successive differences				
High arousal NA	0.44***	0.26***	0.40***	0.32
Low arousal NA	0.25**	0.20*	0.26**	0.13
High arousal PA	0.32***	0.31***	0.07	0.12
Low arousal PA	0.19*	0.19*	−0.00	0.04
Probability of acute change				
High arousal NA	0.44***	0.22**	0.50***	0.40
Low arousal NA	0.31***	0.24**	0.36***	0.22
High arousal PA	0.26**	0.24**	0.14	0.09
Low arousal PA	0.23**	0.23**	0.00	0.05
Inertia				
High arousal NA	−0.18*	−0.14	−0.10	0.04
Low arousal NA	−0.04	−0.06	0.10	0.01
High arousal PA	−0.01	0.02	−0.16	0.02
Low arousal PA	0.03	0.02	−0.12	0.02

Note. Coefficients represent standardized betas. At step 1 HPS was entered to predict each affective dynamic across domains of affect (e.g., high vs. low NA and PA). At step 2, HPS and mean affect (with its corresponding domain) were entered to examine the effects of HPS over-and-above mean affect in daily life.
* $p < .05$. ** $p < .01$. *** $p < .001$.

The literature examining affective dysregulation in bipolar spectrum psychopathology has largely concentrated on mean levels or intensity of PA in the context of hypomanic/manic episodes and has generally overlooked the experience of NA (Johnson et al., 2016). However, findings suggested that bipolar spectrum psychopathology was associated with elevated mean levels of NA in daily life, consistent with our previous findings (Kwapil et al., 2011, Sperry and Kwapil, 2017, Walsh et al., 2012). Furthermore, these findings indicated that bipolar psychopathology was associated with instability of both high and low arousal NA and was characterized by acute increases in NA across moment-to-moment assessments. Coupled with elevated reactivity to negative events and stressful situations, those at risk for the development of bipolar spectrum disorders appear likely to experience intense increases in NA that may produce maladaptive outcomes. In fact, in the present study, instability of high arousal NA accounted for a large proportion of variance in HPS scores (R^2 = 0.30–0.48). Thus, future studies should examine whether acute increases in NA predict maladaptive outcomes such as impulsive decision making in daily life for those at risk for bipolar disorders.

Although previous studies suggested that bipolar disorders are characterized by persistent and elevated levels of PA (e.g., Henry et al., 2003, Gruber, 2011), especially in reaction to positive and rewarding events in daily life (Cuellar et al., 2009, Johnson, 2005, Johnson et al., 2008), daily life studies of bipolar spectrum psychopathology and PA have been inconsistent. For example, Walsh et al., (2012) found that bipolar spectrum psychopathology was associated with exuberance in daily life, but not increased happiness, whereas Kwapil et al., (2011) and Sperry and Kwapil (2017) found that HPS scores were associated with increased energy and happiness in daily life. None of these studies found hyper-reactivity of PA in daily life. The present study did not find mean elevated levels of high arousal PA or low arousal PA, hyper-reactivity to positive or successful events, or high levels of variability of PA. In contrast, HPS scores were associated with instability and acute increases in PA in daily life. This suggests that, in the present sample, individuals high in bipolar spectrum psychopathology generally did not display large dispersions from their mean levels of PA or high levels of mean PA. However, when accounting for adjacent temporal changes, indices of instability showed that high HPS scores were associated with increased variability and diminished temporal dependency over time. This highlights the importance of measuring multiple indices of short-term dynamics of affect as opposed to solely measuring one index of affect (or using measures that do not account for time, e.g., WPV), as researchers may miss important patterns of affective fluctuations relevant to psychopathology. This also has implications given that previous findings showed that instability in PA (as measured by WPV, MSSD, and PAC) in terms of both short- and long-term dynamics was associated with decreased life satisfaction, global functioning, and subjective happiness, as well as increased depression and anxiety after controlling for mean levels of affect (Gruber et al., 2013).

Patterns of affective fluctuations (short-term dynamics) reflect how individuals experience their environment and how they regulate their affect in response to real-world events (Houben et al., 2015, Larsen, 2000). A meta-analysis of studies examining affective dynamics in daily life suggested that distinct profiles of affective dynamics can reflect adaptive/maladaptive or flexible/inflexible affective responses to one's environment (Houben et al., 2015). For example, high levels of variability, instability, and inertia were associated with worse psychological well-being, whereas low variability, instability, and inertia were associated with better psychological well-being and less psychopathology (Houben et al., 2015). Importantly, this meta-analysis highlighted that the least adaptive pattern of short-term affective dynamics was characterized by large deviations from one's mean level on a moment-to-moment basis (high instability) coupled with high levels of inertia, which would reflect that following reactivity, individuals were slower to recover or to return back to their core affect. The present findings indicated that those at risk for the development of bipolar spectrum psychopathology displayed maladaptive patterns of instability in daily life (acute increases in NA and PA that are considered "meaningful" deviations from core affect), but low levels of inertia (indicating that they successfully down-related to core affect following acute increases).

Importantly, associations between HPS scores and affective dynamics (WPV, MSSD, PAC) remained with minimal attenuation after accounting for mean levels of affect. This is a key finding given that mathematical computations of dynamics in daily life have been criticized for being conflated with mean levels of affect (Baird et al., 2006). These findings provide further support for modeling indices of variability, instability, and probability of acute change in daily life as a way to examine the dynamic nature of the experience of affect in daily life.

Note that these findings represent individuals scoring high on the HPS; however, not all of these individuals have or will go on to develop bipolar spectrum disorders. Thus, it is unclear the extent to which these dynamics generalize to clinically diagnosed patients. However, we believe that assessing those high in hypomanic personality offers a useful strategy for studying bipolar psychopathology as previous studies have found that those high on the HPS have a markedly elevated risk of developing bipolar spectrum disorders but not unipolar depressive disorders (Kwapil et al., 2000, Walsh et al., 2015). Thus, studying those high on the HPS appears to be a useful measure for identifying people with bipolar symptoms and heightened risk for bipolar disorders. Future studies should examine affective dynamics across the entire bipolar spectrum, including those high on the HPS and those with diagnosed bipolar disorders.

The present study had several limitations that should be addressed in future research. First, affective dynamic indices used in the present study were only sensitive to short-term fluctuations and limited in their ability to assess longer-term patterns in affective experiences. Thus, future studies should extend ESM sampling times to a minimum of 14 days in order to examine both short- and long-term fluctuations in affect and capture both week and weekend environments (Jahng et al., 2008). Note that Jahng et al., (2008) provides separate formulas for modeling short-term and long-term dynamics for MSSD and PAC. Second, the present study did not assess whether certain affective dynamics (e.g., MSSD) better predict maladaptive outcomes or patterns of behavior over-and-above mean levels of affect. For example, future studies should assess whether affective dynamics provide additional explanatory power, over-and-above mean affect, in predicting maladaptive or adaptive outcomes in daily life. Specifically, in terms of bipolar spectrum psychopathology, future studies could examine whether acute increases in NA or PA (as determined by PAC) are associated with impulsive decision making in the moment, consistent with literature suggesting that bipolar spectrum psychopathology is associated with heightened levels of impulsivity in the face of strong emotions (Johnson et al., 2016, Johnson et al., 2013, Muhtadie et al., 2014, Sperry and Kwapil, 2017). Third, in order to asses NA and PA reactivity, participants rated the item, “The most important event since the last beep was negative/ positive.” Although this item provided information about participants’ subjective ratings of an event, it did not objectively measure reactivity to an event. Importantly, in order to more objectively measure reactivity, future studies should ask “Since the last beep, did you experience and important event (Yes/No)” and subsequently rate the valence of the event from positive to negative. This method would also enable the researcher to collect information about what type of event the participant endorsed via a checklist or qualitative response option. Lastly, this study did not examine the extent to which unique affective dynamics reflect other core aspects of bipolar disorder such as circadian rhythm disruption or diurnal effects. Future studies should examine the extent to which affective dysregulation produces or is a product of circadian disruptions.

5. Conclusions

The examination of affective dynamics in real-world contexts should enhance our understanding of affective dysregulation across subclinical and clinical bipolar spectrum psychopathology. Specifically, understanding short- and long-term affective dynamics may provide context-relevant information about the course and trajectory of bipolar spectrum psychopathology and should facilitate the use of ambulatory assessment to study and intervene in mood lability in patients with bipolar disorders. For example, if acute changes in PA or NA are associated with negative behavioral outcomes (e.g., lack of sleep, impulsive behaviors), mood monitoring applications can disseminate individualized interventions based on algorithms developed to flag risk based on PAC or send a message to providers or family members indicating that the individual may be at risk. Furthermore, psychosocial interventions such as Dialectical Behavior Therapy or Interpersonal and Social Rhythms Therapy should be implemented to target affective reactivity and instability present across the bipolar spectrum.

In terms of assessing affective dysregulation in bipolar disorder, future investigations should examine affective dynamics over longer periods of time to better understand differences in within-day and between-day dynamics and whether these dynamics predict symptoms unique to bipolar disorder or represent a larger transdiagnostic vulnerability to psychopathology. Importantly, researchers interested in assessing affective dynamics in daily life should model multiple indices of affective dynamics and include measures that specifically assess for temporal dependency.

Current models of psychopathology are moving away from narrow categorical models to focus on dimensional models of symptoms and impairment as well as cross-cutting or transdiagnostic mechanisms. We believe that our model of bipolar spectrum psychopathology fits in well with these modern models and with the development, expression, and course of bipolar psychopathology. Furthermore, the study of affective dynamics appears to be an especially promising area of inquiry for understanding the etiology, expression, and maintenance of bipolar spectrum psychopathology. This study provides an important application of modern affective dynamics to the broader construct of bipolar spectrum psychopathology.

Funding. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflicts of interest. Sarah Sperry and Thomas Kwapil have no conflicts of interest to report.

Contributors. Sarah Sperry designed the study and wrote the protocol with support of Thomas Kwapil. Sarah Sperry managed the literature searches. Sarah Sperry undertook the statistical analysis and wrote the first draft of the manuscript. Thomas Kwapil contributed to all subsequent version of the manuscript and approved the final version.

Acknowledgements. We acknowledge Christopher G. Mayne for contributing scripts to synthesize study data. We would like to thank Kathryn C. Kemp for proof-reading and editing of the manuscript.

Supplementary materials. Supplementary material associated with this article can be found at doi:10.1016/j.jad.2019.01.053.

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