A Pilot Study of Ecological Momentary Assessment of Emotion Dysregulation in Children

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ABSTRACT

Background: Emotion dysregulation (EDr) in children is linked to a wide variety of maladaptive outcomes, including externalizing and internalizing behaviors, irritability and aggression, emotional outbursts, and social dysfunction.

Objective: This pilot study examined the feasibility and utility of ecological momentary assessment (EMA) to differentiate patterns of EDr in children with attention-deficit/hyperactivity disorder (ADHD) versus pediatric-onset bipolar disorder (PBD).

Methods: Two elementary school–aged children were assessed to allow for a comparison between a child with ADHD with significant EDr (ADHD-EDr) and a child with PBD. The children's mothers completed ratings of their children's mood, irritability, and affect 3 times per day for 28 days (82 ratings total) using a personal digital assistant. Recurrence Quantification Analysis was used to assess the variability, predictability, stability, and episodic versus chronic nature of the children's mood, irritability, and affect over the study period.

Results: The child with PBD demonstrated more variability and stability and less predictability across all ratings than the child with ADHD-EDr. Further, the child with ADHD-EDr demonstrated a chronic pattern of dysregulation across all ratings, while the child with PBD demonstrated episodic variation in dysregulation.

Conclusions: The study provides encouraging evidence for the feasibility and utility of using EMA to assist in further defining and differentiating patterns of EDr across PBD and ADHD. (*J ADHD Relat Disord.* 2010;1[4]:39–52) © 2010 Excerpta Medica Inc.

Key words: ADHD, bipolar disorder, emotion dysregulation, ecological momentary assessment.

INTRODUCTION

Emotion regulation is the fundamental process by which individuals modulate their internal emotional states to meet internal and external demands.[1] Emotion regulation requires the continual and simultaneous activation of physiological, neurological, cognitive, and behavioral systems to maintain adaptive emotional states and ameliorate maladaptive emotional states.[2] Emotion dysregulation (EDr) occurs when individuals are unable to successfully modulate their emotional states to fit their internal or environmental needs. Children who are unable to effectively regulate emotions are at risk for a broad range of emotional, behavioral, social, and adaptive impairments.[3] Dickstein and Leibenluft[4] describe EDr as a "primary contributor" towards emotional and behavioral impairment in children.

EDr in children is linked to a wide variety of maladaptive outcomes, including externalizing and internalizing behaviors, irritability and aggression,[5] emotional outbursts,[6] and social dysfunction.[7] Children with EDr are more emotionally labile than well-regulated children, as they demonstrate more

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emotional distress, lower thresholds for distress, more intense and longer-lasting reactions to distress, and greater difficulty reducing distress.[3] EDr has increasingly been recognized as either a core feature or associated contributor to several disorders, including internalizing disorders (eg, mood disorders, certain anxiety disorders) and externalizing disorders (eg, attention-deficit/hyperactivity disorder [ADHD], disruptive behavior disorders).

EDr and ADHD

EDr has been identified as a "core component" of ADHD.[8] Barkley[8] and Skirrow et al[9] reviewed studies demonstrating evidence of physiological, neurological, cognitive, and behavioral markers of EDr in children with ADHD. Geller et al[10] reported that irritable mood was present in 71.6% of a sample of children diagnosed with ADHD, while Skirrow et al[9] indicated that children with ADHD experienced more emotional instability, were less able to regulate emotions, and demonstrated greater irritability and emotional explosiveness than typically functioning children. Barkley[8] and Carlson[11] both noted that EDr-based symptoms such as irritability, explosive behavior, and emotional lability were actually listed as criteria in early formulations of ADHD.

While Barkley[8] and others have identified EDr as a core component of ADHD, studies have also noted substantial variability in EDr among children with ADHD.[12] Notably, studies have identified a subset of children with ADHD who experience significantly severe EDr.[5] Children with ADHD who are more severely emotionally dysregulated demonstrate greater emotional, behavioral, and social difficulties than their more well-regulated counterparts,[6,12] including irritability, aggression, emotional distress, and more severe ADHD symptomatology (particularly hyperactive/impulsive symptoms).[6,9,12,13] EDr in children with ADHD has been linked with significantly increased rates of comorbid internalizing and externalizing diagnoses, including disruptive behavior disorders and depression,[13] and some have posited EDr as a common factor underlying ADHD and comorbid internalizing/externalizing pathology.[14] However, EDr remains inconsistently defined and classified among children with ADHD,[4,11] in part because current diagnostic classification systems do not comprehensively account for the difficulties seen in children with severe EDr (ie, chronic irritability, mood instability, and emotional intensity). As a result, the ADHD-EDr subgroup has been inconsistently identified and labeled in both research literature and clinical practice[15] (ie, "Severe Mood Dysregulation," "Broadband pediatric-onset bipolar disorder [PBD]," "comorbid ADHD").

EDr in ADHD Versus Pediatric Bipolar Disorder

There has been an increasing tendency in recent years among both clinicians and researchers to classify children with severe and chronic EDr according to the PBD criteria (particularly as bipolar not otherwise specified [NOS][15,16]). PBD is by definition a disorder of EDr,[5] and studies have noted that children with PBD demonstrate impaired physiological, neuropsychological, affective, and behavioral regulation of positive and negative emotions.[15] Accordingly, rates of PBD diagnoses have skyrocketed in recent years, with increases of 200% to 400% over the past decade across outpatient and inpatient settings.[15] There has been considerable controversy regarding this extension of PBD to account for children with the chronic patterns of EDr seen among children with ADHD.[4,11] Much of this debate concerns whether children with ADHD-EDr are being misclassified as PBD. Carlson and Meyer[17] noted that "EDr is central to the debate regarding PBD." Many investigators believe that the EDr observed in children with ADHD-EDr is structurally different from the EDr observed in PBD,[5] and studies have demonstrated etiological, neurological, and symptomological distinctions between children who meet *Diagnostic and Statistical Manual of Mental Disorders,* Fourth Edition (*DSM-IV*) criteria for PBD and children who demonstrate severe EDr in the context of ADHD.[15] Accordingly, it has been proposed that a distinct diagnostic category ("Temper Dysregulation Disorder"[18]) be created to account for children with severe but nonepisodic EDr.

Patterns of EDr

EDr encompasses several temporal facets of emotional experience, including variability, instability, predictability, and episodicity (ie, episodic versus

chronic) of emotional arousal.[1,4,19] The facets describe interrelated yet distinct dynamic features of the temporal structure of emotional variability.[19,20] Eaton and Funder[21] demonstrated that different facets of EDr were associated with distinct forms of psychological dysfunction. The following facets have been identified.[19,20]

(1) **Variability**: the degree to which children's emotional states vary around a set point (**Figure 1a**). The set point reflects the child's typical (trait level) emotional state, whether positively or negatively valenced.[22] Children with PBD have been described as more emotionally variable than children with ADHD-EDr.[10]

(2) **Stability/Instability**: the extent that children maintain consistent emotional states over time, whether aroused or at set point (ie, a depressed child may demonstrate stable but intensely negative emotional states[22]; **Figure 1b**). Emotional instability over time is a hallmark feature of PBD,[10] and is also common to a lesser extent in ADHD-EDr.[8]

(3) **Chronicity/Episodicity**: the patterned rate of change of a child's emotional state.[22] Children with chronic patterns of arousal demonstrate arousal around a fixed emotional set point, while children with episodic patterns of arousal demonstrate changes in the set point itself[4] (**Figure 1c**). Episodicity has been described as a "cardinal symptom" of PBD[10] and the primary differential feature of PBD versus ADHD-EDr.[5] Episodicity is rarely seen in ADHD-EDr regardless of the severity of other facets of EDr.[10]

(4) **Predictability/Unpredictability**: the degree of patterned structure within the child's emotional arousals over time (ie, in fairly predictable sequences or as unpredictable "affective storms"; **Figure 1d**).[16,19] Unpredictability of emotions has not been thoroughly studied in children.

Assessment of EDr

Limitations of Current Measures of EDr

To date, most studies of EDr have used retrospective report instruments (eg, Kiddie Schedule for Affective Disorders and Schizophrenia for School-Age Children [KSADS], Emotion Regulation Checklist) or laboratory-based physiological evaluation to assess EDr in children. Retrospective report interviews and rating scales provide useful information regarding overall EDr, but typically collapse across time points (and facets) to provide a single rating of EDr.[3,23] These measures also rely on retrospective reports, which are susceptible to cognitive biases, such as recency effects, emotional salience, summing across events, and recall deficiencies,[24] and often do not accurately or fully capture the temporal structure of emotional fluctuations. Of note, while some measures (eg, KSADS) provide information regarding diagnosis of disorders with EDr components, no measure to date has provided clinical norms or cutoffs regarding severity of EDr. Conversely, physiological assessment of EDr traditionally measures physiological markers of emotional arousal in response to single time-point laboratory-based experimental stimuli,[2] which does not provide information regarding long-term fluctuation. Although rating scales and physiological assessment both provide considerable information regarding EDr, neither method is able to capture the dynamic temporal structure of EDr.

Ecological Momentary Assessment of EDr

Ecological momentary assessment (EMA) provides an ideal methodology to assess the temporal patterns of EDr in children. EMA describes methodologies developed to collect real-time data from participants within the context of their typical daily lives.[24] Rating scales are completed by participants (or their parents) directly on personal digital assistants (PDAs) several times during the day.[24] EMA provides substantially more accurate response data than retrospective or summary reports, even when compared with end-of-day recall.[24] EMA-based data collection allows for control of the times at which rating scales may be completed and is substantially less susceptible to cognitive biases, increasing the reliability of time-linked reporting.[24] EMA holds substantial promise for the assessment of patterns of EDr over time. Two studies in particular have demonstrated the potential utility of EMA in examining the temporal structure of EDr. Axelson et al[25] reported that more than 80% of study participants (affectively disordered adolescents) were able to complete an 8-week EMA protocol, and case studies demonstrated clear differentiation in the patterns of

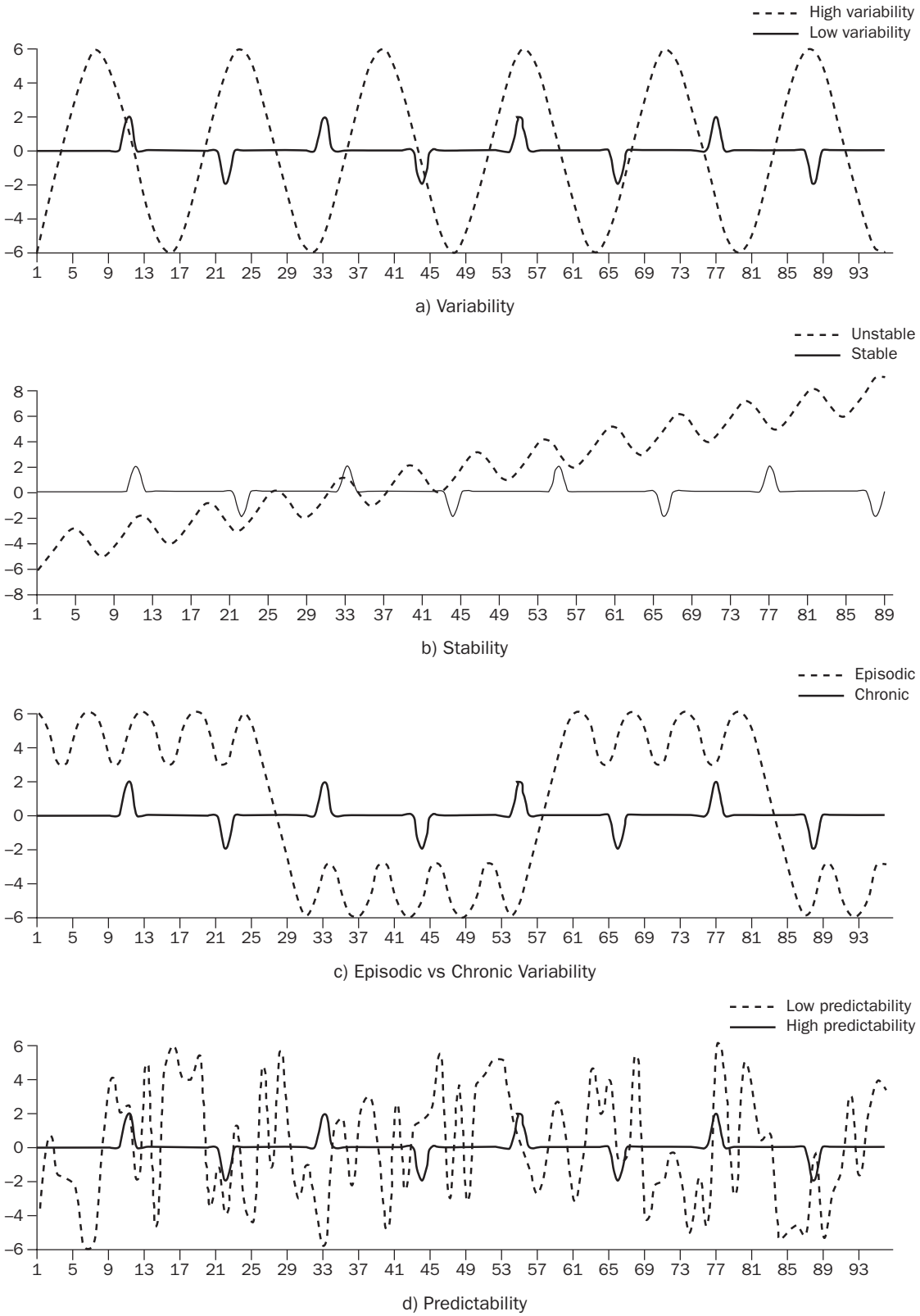

Figure 1. Examples of the facets of EDr. Each graph represents 2 extremes of the dimensions of interest. The dimensions of interest have been exaggerated. The same comparison line is used for all 4 graphs. EDr = emotion dysregulation.

emotional fluctuation exhibited by children across differing mood disorder conditions. Chow et al[19] were able to determine the temporal structure of the emotional fluctuations of college students who completed ratings once per day for a 52-day period. EMA represents a substantial advance on retrospective reports and laboratory-based physiological observation of EDr.

Current Pilot Study

The purpose of the present study was to examine the feasibility and utility of using EMA technology using case studies to assess differential patterns of emotion regulation among clinic-referred children with ADHD-EDr versus PBD. It was hypothesized that parents would be able to complete at least 80% of all assessment points across the study period. It was hypothesized that ratings of the mood, irritability, and affect of a child with ADHD-EDr would demonstrate a pattern of lower variability, higher predictability, and higher stability compared with that of a child with PBD. It was further hypothesized that the ratings of a child with ADHD-EDr would be characterized by a pattern of chronic but consistent dysregulation, while those of a child with PBD would reflect a pattern of EDr.

METHODS

Screening/Participants

Parents of children referred to an ADHD clinic and a pediatric mood disorders clinic were contacted to determine interest in participating in the present study. To ensure that their children met criteria either for ADHD-EDr or PBD, parents completed (1) the *Vanderbilt ADHD Parent Rating Scales*[26] (VADPRS), a *DSM*-based symptom inventory of ADHD; (2) the *Child Behavior Checklist*[27] (CBCL), a broadband measure of internalizing and externalizing behaviors; and (3) the *General Behavior Inventory – Parent Version, Short Form*[28] (PGBI), a 10-item screener of mania symptoms. Parents also completed the *Diagnostic Interview Schedule for Children-Parent Version 4.0* (DISC-P). The following criteria were specified for participation in this study:

– *ADHD-EDr:* ≥6 symptoms on VADPRS Inattention *and* Hyperactive/Impulsive scales; AND T ≥65 on CBCL-Internalizing *and* CBCL-Externalizing; AND PGBI <14.

– *PBD:* T ≥65 on CBCL-Internalizing *and* CBCL-Externalizing; AND PGBI ≥14.

Thresholds on the CBCL were determined according to Youngstrom et al's[28] recommendations. Thresholds on the PGBI were determined according to the cutoff identified by Youngstrom et al.[28] The first children to meet criteria for 1 of the 2 categories were enrolled in the study. The following 2 children were enrolled in the study.

ADHD-EDr

Dylan was a 9-year-old white male entering fourth grade. At the time of assessment, Dylan lived in a single-parent household. All ratings were completed by his mother. Dylan had received a primary diagnosis of ADHD-combined type prior to his participation in the study, and was on a consistent dose of stimulant medication (27 mg methylphenidate) throughout the study. Dylan's mother's rating scale results indicated significant symptoms of inattention (VADPRS = 9 of 9 symptoms) and hyperactivity/impulsivity (VADPRS = 6 of 9 symptoms), as well as broad-spectrum internalizing (CBCL-Internalizing = 65T, 93rd percentile) and externalizing (CBCL-Externalizing = 71T, 98th percentile) behavior. His mother did *not* indicate significant symptoms of mania (PGBI Total = 4). On the DISC-P, Dylan met criteria for ADHD-combined type and oppositional defiant disorder (ODD).

PBD

David was an 8-year-old white male entering third grade. At the time of assessment, David lived in a single-parent household. All ratings were completed by his mother. David had been diagnosed with ADHD-combined type and ODD prior to his participation in the study, but was concurrently being evaluated for a primary diagnosis of bipolar disorder I. David was on a consistent dose of stimulant medication (20 mg mixed amphetamine salts) throughout the study. David's mother's rating scale results indicated significant symptoms of inattention (VADPRS = 8 of 9 symptoms) and hyperactivity/impulsivity (VADPRS = 9 of 9 symptoms), as well as broad-spectrum internalizing

(CBCL-Internalizing = 71T, 98th percentile) and externalizing (CBCL-Externalizing = 72T, 99th percentile) behavior. Her results *did* indicate significant symptoms of mania (PGBI Total = 22). On the DISC-P, David met criteria for ADHD-combined type, ODD, and mania (mother endorsed 9 of 13 symptoms, but denied impairment from his mania symptoms).

EMA Procedures

Parents were provided with a preprogrammed Palm® Z22 PDA (Palm, Inc., Sunnyvale, California), which had been programmed using Purdue Momentary Assessment Tool software (PMAT) (Purdue University, West Lafayette, Indiana).[29] The PDA was programmed to set off alerts at 3 specific predetermined intervals (before school, after school, and evening) requested by parents to be compatible with the family's schedule. Prior to initiating EMA, parents completed a 15-minute training and practice session regarding use of the PDA. Parents were prompted to complete ratings at each time point in the presence of their child. At each time point, parents were asked to report on their child's current mood, irritability, and affect. Parents completed ratings with the PDA 3 times daily for a period of 28 days to ensure that assessments captured a full range of temporal emotional variation, as well as to ensure an adequate number of rating points to complete analyses. Children were not asked to complete ratings for this study given the concerns regarding their ability to accurately complete ratings (particularly while dysregulated), as well as their capacity to safely and responsibly operate the PDA.

To enhance compliance with EMA procedures, parents were asked to return to the laboratory each week to allow data to be uploaded from the PDA. At each visit the parent was provided with a "score card" regarding their adherence to the procedures over the previous week. Parents received monetary compensation for their participation, with compensation prorated to reflect the percentage of completed intervals and weekly "adherence bonuses" available to parents who completed >80% of intervals over the previous week. To further enhance compliance, parents were also provided opportunities to modify the schedule of PDA alerts and receive technical support regarding the PDA performance at each of these visits. Parents were also allowed to contact investigators during the week regarding technical support.

EMA Ratings

Mood Rating

Parents were asked to rate their child's mood *at the time of the assessment* using a visual analog scale (VAS) at each assessment interval. Parents completed a VAS stating, "What is your child's mood *right now?*" directly on the PDA. As mood is widely considered to be homeostatic,[22] parents rated their child's mood on an 11-point scale ranging from –5 to +5, whereby –5 = "much worse mood than usual," 0 = "typical mood for my child," and +5 = "much better mood than usual."

Irritability Rating

Parents were also asked to rate their child's irritability level *at the time of the assessment* using a VAS at each assessment interval. Parents completed a VAS stating, "How irritable is your child *right now?*" directly on the PDA. Parents rated their child's irritability on a scale of 1 to 10, with greater numbers reflecting greater irritability.

The Positive and Negative Affective Scale – Parent Report[30] (PANAS-PR)

Parents were asked to complete a parent-report form of the PANAS directly on the PDA at each assessment interval. The PANAS-PR is a 27-item measure that was developed as a parent-report analogue of the child-report PANAS. Parents were presented with adjectives describing positive (eg, *excited, proud*) or negative (eg, *upset, irritable*) mood states, and asked to rate the presence or absence of that mood state in their child on a 5-point Likert scale ("not at all" to "extremely"). The measure yields 2 subscales, Positive Affect (PA) and Negative Affect (NA). Parents were explicitly instructed to report on their child's *current* emotions at each assessment time point.

Recurrence Quantification Analysis

EDr is by definition a nonlinear and temporal phenomenon that presents variably across individuals. Studies of EDr have typically relied on aggregate data

and linear measures of variance (eg, standard deviations) to assess intraindividual emotional variability. However, aggregate measures of emotional variability "fail to acknowledge sequential dependence"[31] and do not provide any information about the *patterns* of variability.[20] Studies using conventional linear analysis may thus account for one facet of EDr (eg, variability or intensity), but do not accurately capture the full dynamic pattern of emotional fluctuation over time. Conventional linear methods of time series analyses (eg, ARMA [Auto Regressive Moving Average] models, autocorrelation) are similarly limited in their ability to examine fluctuations in emotional state,[31] as the basic assumptions of these methods are violated by time or data series where the mean is nonstationary (as would be seen in episodic patterns of emotional fluctuation).

By contrast, nonlinear methodologies such as Recurrence Quantification Analysis (RQA) have been developed to capture the dynamic structure of an individual temporally dependent data series.[32] RQA derives recurrence plots by computing the distances between all possible data points in the multidimensional "phase space." RQA uses "pattern recognition algorithms" to assess the manner in which values repeat within this "phase space" to detect subtle and intrinsic structural dynamics of the time series.[32] RQA is conducted on an individual temporal data series, and yields several statistics of specific facets of the fluctuation patterns of a temporal data series that cannot be obtained through linear analysis. Specifically, RQA yields the following statistics: (1) percentage recurrence (%REC): the extent to which values repeat in a temporal data series. Lower %REC is indicative of more *variability*, as it reflects mood differing from a "set point"; (2) percentage determinism (%DET): the extent to which specific sequences of data reappear within a data series. Lower %DET is indicative of *unpredictability*; (3) mean line (MnL): the average length of repeating sequences within the temporal series. Lower MnL indicates more *instability*, as it indicates that the average repeating sequence (ie, period of stable mood) is of shorter duration; and (4) trend (TND): measure of how stationary is the mean of the data series. Higher absolute TND indicates *nonstationary mean*, as in random, stochastic, or episodic data series. RQA is already used widely in the physical and biological sciences but has only recently been applied to the behavioral sciences.[32] RQA is a powerful and innovative methodology for identifying disparate patterns of EDr among children with ADHD-EDr versus PBD. The data were analyzed using customized programming[31] within MatLab (The MathWorks, Inc., Natick, Massachusetts).

RESULTS

Feasibility

Participants completed 79/82 (96.3%; ADHD-EDr child) and 71/82 (86.6%; PBD child) of the assessment intervals, respectively. Neither participant missed 2 or more consecutive assessment intervals.

EMA Analyses

Mood

The mood variability ratings of the child with PBD suggest a pattern of episodic mood variability, with notably more variable and elevated mood over the initial portion of the assessment period and more consistent mood over the latter portion of the period. By contrast, the mood ratings of the child with ADHD-EDr appear to be consistent with a pattern of typically consistent mood interspersed with chronically appearing discrete single instances of negative mood (**Figure 2**).

Quantitative analyses of the EMA mood ratings indicated several differences in the pattern of variability demonstrated by children with ADHD-EDr versus PBD. Notably, while the child with PBD demonstrated a more positive overall mood than the child with EDr (**Table**), RQA suggested that his mood was also markedly more dysregulated. Specifically, analyses indicated that the child with PBD demonstrated more variability (%REC = 15.01% vs 27.45%), less predictability (%DET = 33.70% vs 50.33%), and more episodic (TND = 265.28 vs 54.22) mood than did the child with ADHD-EDr (**Table**). No noticeable differences were noted in mood stability.

Irritability

The irritability ratings suggest a pattern of discrete episodes of varying irritability in the child

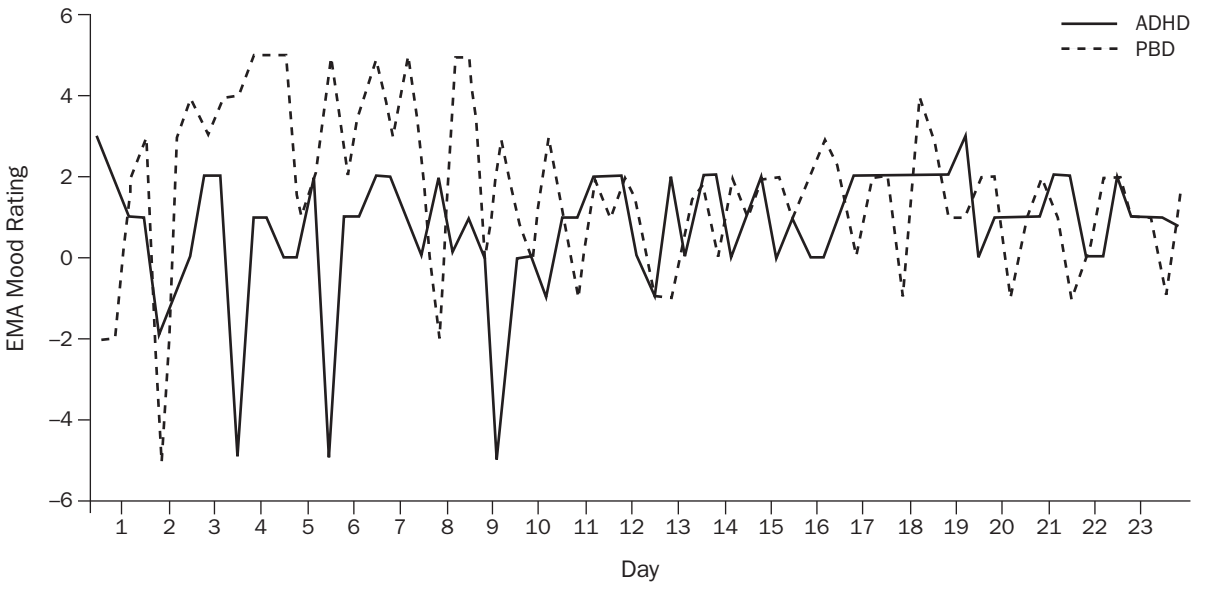

Figure 2. EMA ratings of mood. EMA = ecological momentary assessment; ADHD-EDr = attention-deficit/hyperactivity disorder-emotion dysregulation; PBD = pediatric-onset bipolar disorder.

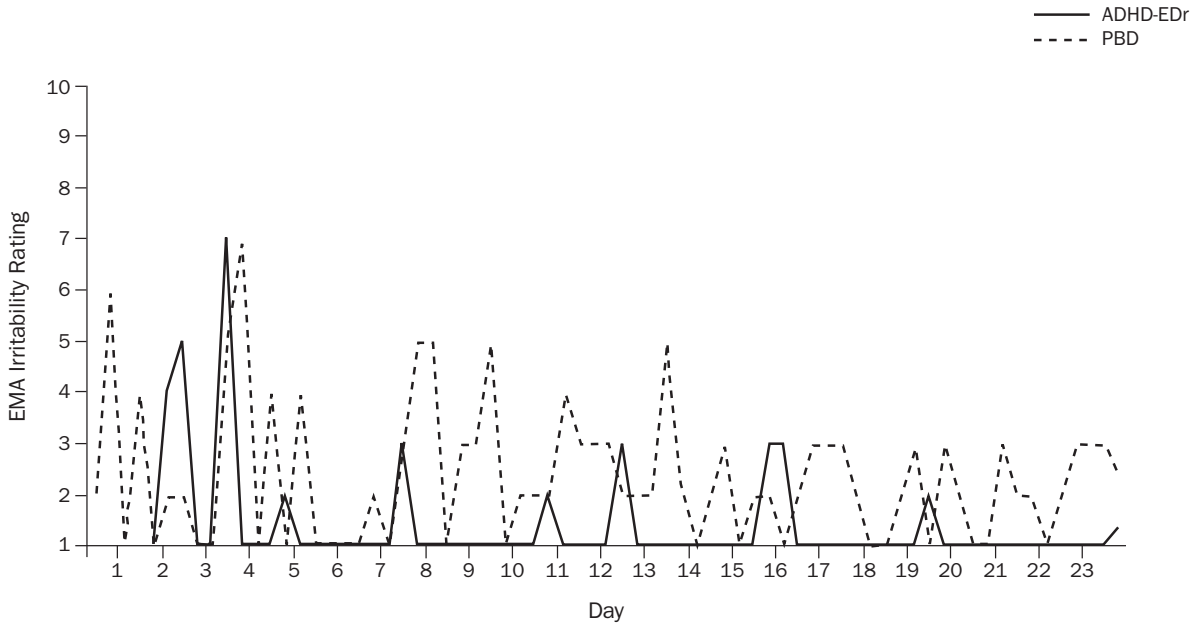

Figure 3. EMA ratings of irritability. EMA = ecological momentary assessment; ADHD-EDr = attention-deficit/hyperactivity disorder-emotion dysregulation; PBD = pediatric-onset bipolar disorder.

with PBD, with more variable and greater irritability at the start of the assessment period and more consistent low-level irritability over the latter portion of the assessment period. By contrast, ratings of the child with ADHD-EDr appear consistent with a pattern of chronic low-level irritable arousals (**Figure 3**). Qualitative analyses of the EMA irritability ratings indicated several differences in the pattern of variability demonstrated by the children with ADHD-EDr versus PBD. The child with PBD demonstrated much more overall irritability than the child with EDr, although RQA also suggested notable differences in the pattern of irritability. Specifically, analyses indicated that the

TABLE. EMA RATING AND RQA RESULTS.

	Mood		Irritability		PANAS-PA		PANAS-NA	
	ADHD-EDr	PBD	ADHD-EDr	PBD	ADHD-EDr	PBD	ADHD-EDr	PBD
Mean	0.77	1.68	1.34	2.37	1.43	4.13	1.06	2.48
%REC	27.45	15.01	79.96	23.89	35.75	35.24	67.39	42.48
%DET	50.33	33.70	97.65	40.38	73.75	76.62	91.59	77.39
MnL	2.33	2.21	5.45	2.33	2.95	2.00	4.22	3.08
Trend	54.22	265.28	82.12	141.45	312.07	1103.01	52.07	826.12

EMA = ecological momentary assessment; RQA = Recurrence Quantification Analysis; PANAS-PA = Positive and Negative Affective Scale-Positive Affect; PANAS-NA = Positive and Negative Affective Scale-Negative Affect; ADHD = attention-deficit/hyperactivity disorder; EDr = emotion dysregulation; PBD = pediatric-onset bipolar disorder; %REC = percentage recurrence; %DET = percentage determinism; MnL = mean line.

Notes regarding RQA statistics:

1. %REC used as an indicator of variability. Lower %REC indicates greater variability.
2. %DET used as an indicator of unpredictability. Lower %DET indicates greater unpredictability.
3. MeanLine used as an indicator of instability. Lower MeanLine indicates greater instability.
4. Trend used as an indicator of episodicity. Higher trend indicates greater instability.

child with PBD demonstrated more variable (%REC = 23.89% vs 79.96%), more unpredictable (%DET = 40.38% vs 97.65%), more unstable (MnL = 2.33 vs 5.45), and more episodic (TND = 141.45 vs 82.12) irritability than did the child with ADHD-EDr (**Table**).

PANAS-PA

The PANAS-PA ratings are consistent with the proposed pattern of chronic versus episodic EDr, with the child with ADHD-EDr demonstrating chronically low positive affect and the child with PBD demonstrating evidence of episodic variation in positive affect (**Figure 4**). Qualitative analyses of the EMA PANAS-PA ratings indicated several differences in the pattern of variability demonstrated by the child with ADHD-EDr versus the child with PBD. Notably, while the child with PBD demonstrated a markedly greater overall positive affect than the child with EDr (**Table**), RQA suggested that his mood was also markedly more dysregulated. Specifically, analyses indicated that the child with PBD demonstrated positive affect that was noticeably more unstable (MnL = 2.00 vs 2.95) and episodic (TND = 1103.01 vs 312.07) than the child with ADHD-EDr. No differences were noted in variability or predictability.

PANAS

Irritability ratings suggest a pattern of discrete episodes of negative affect among the child with PBD, with lower negative affect at the start of the assessment period and higher negative affect over the latter portion of the assessment period. By contrast, ratings of the child with ADHD-EDr appear to be consistent with a pattern of chronic low-level arousals of negative affect (**Figure 5**). Qualitative analyses of the EMA PANAS-NA ratings indicated several differences in the pattern of variability demonstrated by the child with ADHD-EDr versus the child with PBD. The child with PBD demonstrated much more overall negative affect than the child with EDr (**Table**). RQA suggested notable differences in the pattern of variation of negative affect as well. Specifically, analyses indicated that the child with PBD demonstrated more variable (%REC = 42.48% vs 67.39%), more unpredictable (%DET = 77.39% vs 91.59%), more unstable (MnL = 3.08 vs 4.22), and more episodic (TND = 826.12 vs 52.07) negative affect than did the child with ADHD-EDr (**Table**).

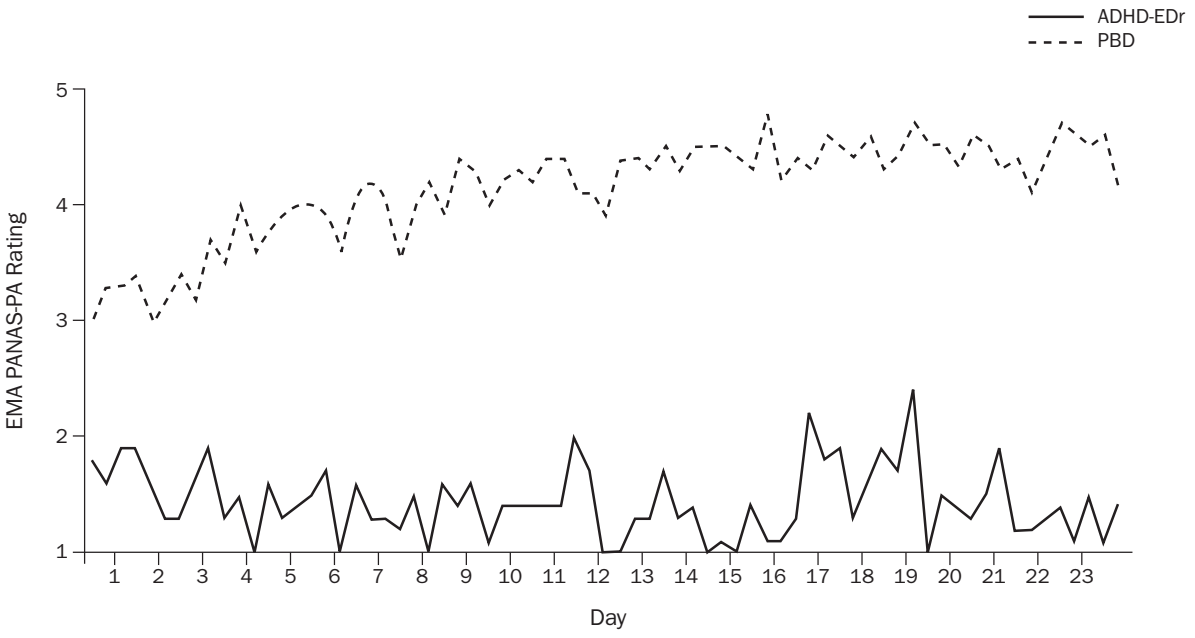

Figure 4. EMA ratings of PANAS-PA. EMA = ecological momentary assessment; PANAS-PA = Positive and Negative Affective Scale-Positive Affect; ADHD-EDr = attention-deficit/hyperactivity disorder-emotion dysregulation; PBD = pediatric-onset bipolar disorder.

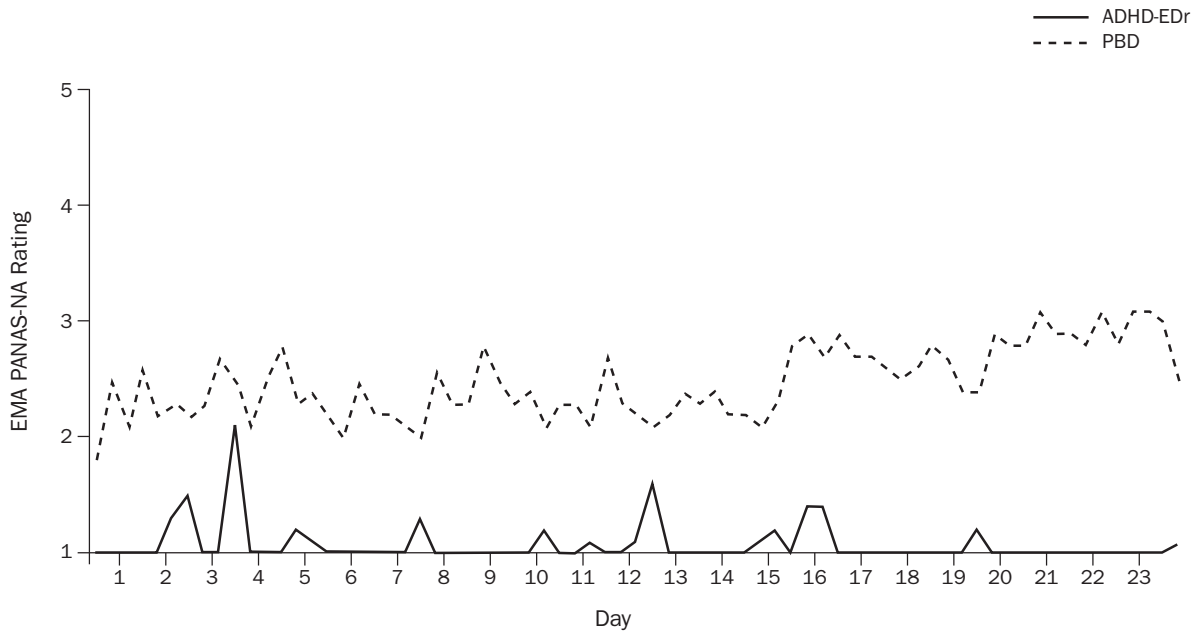

Figure 5. EMA ratings of PANAS-NA. EMA = ecological momentary assessment; PANAS-NA = Positive and Negative Affective Scale-Negative Affect; ADHD-EDr = attention-deficit/hyperactivity disorder-emotion dysregulation; PBD = pediatric-onset bipolar disorder.

DISCUSSION

The present case studies demonstrated the feasibility and utility of using EMA-based methodologies to assess differential patterns of EDr in children with ADHD-EDr versus PBD. Parents of each of the children in the study were able to rate their child's mood, irritability, and affect during at least 85% of the 82 rating points over the 28-day study assessment period (3 ratings per day/28 days). Notably, differential patterns of dysregulation of mood, affect, and irritability emerged among the 2 children. Consistent with the study's hypothesis, the child with ADHD-EDr demonstrated a pattern of chronic but consistent dysregulation, while the child with PBD demonstrated a considerably more episodic pattern of dysregulation.

The child with ADHD-EDr demonstrated a pattern of consistently low positive affect and generally stable mood, with chronic "outbursts" throughout the 28-day period of negative affect, poorer mood, and greater irritability. Notably, RQA results suggested low episodicity, as the child's mean level of mood, irritability, and positive and negative affect remained generally consistent across the study period, despite variability in the actual ratings. This pattern of dysregulation is consistent with Dickstein and Leibenluft's[4] hypothesized description of a "Severe Mood Dysregulation" subset of children with ADHD. Specifically, Dickstein and Leibenluft[4] noted that children within this group demonstrate "chronic, nonepisodic irritability that is operationalized by having a baseline negative mood… and markedly increased reactivity to negative emotional stimuli manifesting verbally or behaviorally." In essence, the ADHD-EDr pattern is characterized by "baseline" and "irritated" states. During the baseline state, the child demonstrates low positive affect with or without accompanying negative affect. The child remains in the baseline state unless aroused by a stimulus that provokes a negative emotion, at which point the child becomes irritable and distressed. Following resolution of the incident, the child's mood returns to the baseline state. This pattern is consistent with the pattern of dysregulation demonstrated by the ADHD-EDr child in the present study, as he demonstrated generally low positive affect along with 10 single time-point ratings of mild to moderate irritability over the 4 weeks.

By contrast, the pattern of dysregulation demonstrated by the child with PBD was considerably more variable over the course of the study. Specifically, ratings for the child with PBD can best be characterized as episodic, with 2 discrete phases evident in the ratings. An initial phase lasting for the first 23 to 26 rating points (8–9 days) was evident in the ratings whereby the child demonstrated substantially elevated mood *and* irritability along with generally lower positive *and* negative affect. Of note, the child's mood and irritability were also notably variable during this initial phase around this elevated mean. By contrast, the child's ratings shifted dramatically over the following 50 to 60 rating points (17–20 days), with a pattern of more euthymic (ie, centered around the "typical" rating) mood, decreased irritability, and increased positive *and* negative affect emerging. Notably, the variability of the child's mood and irritability appeared to decrease noticeably during this phase as well. RQA results were consistent with this interpretation of the child's results, as the higher TND statistics indicated that the mean of the child's ratings shifted over the course of the assessment period, suggesting episodic rather than chronic variability.

This study represents an initial attempt to address substantial gaps in the assessment and classification of EDr in childhood. EDr has emerged as a construct of substantial clinical and theoretical importance in recent years, yet there continues to be debate regarding both its definition and most valid means of assessment.[1] Nowhere has this been more apparent than in the efforts to delineate and differentiate patterns of EDr among children with ADHD-EDr versus PBD.[4] EDr is a core component of both areas of difficulty; however, evidence increasingly supports the conceptualization of children within these groups as experiencing distinct *patterns* of EDr rather than as subgroups of a single disorder (eg, PBD). The present pilot study provides very encouraging initial evidence of the feasibility and usefulness of the EMA-based methodology in demonstrating critical differences in EDr patterns of children with ADHD-EDr and PBD.

Clinically speaking, children within both subgroups demonstrate considerable irritability, negative mood, and emotional and behavioral distress; however, the *patterns* of disruption distinguish the 2 disorders.[5] It can be very difficult for parents to accurately observe and report the temporal sequences of EDr experienced by their children. EMA offers considerable utility above and beyond conventional methods of assessing EDr by allowing the real-time sequences of EDr to be mapped and compared. EMA allows for assessment not just of the variability of the construct of interest, but of *changes in the variability* at different time points. A larger-scale study using the described methodology has the potential to provide information regarding the different types of mood patterns across disorders. Such understanding may eventually aid in defining diagnostic mood symptoms, which should help in the differential diagnosis of a variety of pediatric conditions (eg, ADHD-EDr, ODD, PBD).

Limitations

The present study has several limitations that need to be acknowledged. First and foremost, this was an N = 2 case study. The present study demonstrated differences in the patterns of EDr among the 2 subjects that were prescreened to ensure that they met "prototypic" criteria for the 2 subgroups of interest. Thus, the generalizability of the results is limited. Further, the N = 2 design did not allow for significance testing of any of the differences between the 2 subjects. This is particularly limiting when examining the EMA ratings and RQA results, as there are no clinical norms or comparison groups by which the meaningfulness of the differences can be assessed. Additionally, both children met criteria for ODD on the DISC-P, which has often been associated with EDr.[4] However, behavior difficulties in general and ODD specifically are more commonly conceptualized as an outcome of EDr rather than a cause.[14] Moreover, the 2 children demonstrated substantially divergent patterns of EDr despite the shared diagnosis. Another limitation concerns the assessment methodology. The PDA-based ratings allow for multiple assessments of mood, behavior, and irritability, but do not provide information about the context of the ratings. There are multiple internal and environmental factors that can impact mood, behavior, and irritability, and it was not possible to determine why a child's ratings were elevated or decreased at any time point. The 28-day assessment period also provided a limitation to this study, particularly given the episodic nature of the child with PBD ratings. Finally, it must be acknowledged that the PDA-based assessment methodology has several costs, including both the material cost of the PDAs and the time cost to the participants. However, both parents were able to complete greater than 85% of assessments, and both indicated in informal feedback that completing ratings did not represent a major inconvenience in their daily routines.

CONCLUSIONS

With the recent sharp increase in new diagnoses of PBD,[15] it has become increasingly important to improve the ability of clinicians and researchers to differentiate between "true" PBD and other patterns of EDr. EDr in children can take many forms, and differentiating patterns of EDr can be very challenging. The present study provided encouraging evidence for the feasibility and utility of EMA as a tool to assist in further defining and differentiating patterns of EDr across PBD and ADHD, which may substantially improve our ability to understand, conceptualize, and provide services to these vulnerable groups of children.

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