Published in final edited form as:
J Exp Child Psychol. 2011 October ; 110(2): 241–257. doi:10.1016/j.jecp.2010.10.007.

Daily Emotional Dynamics in Depressed Youth: A Cell-Phone Ecological Momentary Assessment Study

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Abstract

This study utilized a new cellular phone ecological momentary assessment approach to investigate daily emotional dynamics in 47 youth with Major Depressive Disorder (MDD) and 32 no psychopathology controls (CON), ages 7 – 17. Information about emotional experience in the natural environment was obtained using answer-only cellular phones while MDD youth received an 8 week course of cognitive behavioral therapy and/or psychopharmacological treatment. Compared to CON youth, MDD youth reported more intense and labile global negative affect, greater sadness, anger, and nervousness, and a lower ratio of positive to negative affect. These differences increased with pubertal maturation. MDD youth spent more time alone and less time with their families than CON youth. Although differences in emotional experiences were found across social contexts, MDD youth were more negative than CON youth in all contexts examined. As the MDD participants progressed through treatment, diagnostic group differences in the intensity and lability of negative affect decreased, but there were no changes in the ratio of positive to negative affect or measures of social context. We discuss methodological innovations and advantages of this approach, including improved ecological validity and access to information about variability in emotions, change in emotions over time, the balance of positive and negative emotions, and the social context of emotional experience.

Keywords

ecological momentary assessment; experience sampling; depression; emotionality; emotion regulation; social context; psychotherapy

Emerging evidence indicates that child and adolescent depression is associated with disruptions in the experience and regulation of emotion, especially in the social context (Sheeber, Hyman, & Davis, 2001; Silk, Vanderbilt-Adriance et al., 2007). Initial evidence suggests several alterations in emotional experience that appear to be involved in the phenomenology of child and adolescent depression, including: (1) increased intensity, frequency, and/or duration of negative affect (Larson, Raffaelli, Richards, Ham, & Jewell, 1990; Sheeber, Allen, Davis, & Sorensen, 2000; Silk, Steinberg, & Morris, 2003), (2) decreased positive affect and reward seeking (Forbes & Dahl, 2005), (3) increased

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variability or "lability" of negative emotion (Larson et al., 1990; Silk et al., 2003), (4) limited or maladaptive social, cognitive, and behavioral strategies for managing emotion (Garber, Braafladt, & Weiss, 1995), and (5) difficulty managing emotion within interpersonal contexts due to interpersonal sensitivity or conflict (Rudolph, Hammen, & Burge, 1997; Sheeber et al., 2000). Despite rapidly growing interest in these questions, there is still little empirical study of the affective and social changes at the core of pediatric depressive disorders, and limited understanding of which changes may be linked to the etiology of depression in youth (Axelson et al., 2003).

Limitations in approaches to measuring emotionality and emotion regulation (see Cole, Martin, & Dennis, 2004), especially among older children and adolescents, likely play a role in limiting advances on this topic. Most of the small number of studies examining emotionality in samples of clinically diagnosed depressed youth have been conducted in laboratory settings using emotional information processing tasks (Jazbec, McClure, Hardin, Pine, & Ernst, 2005; Pine et al., 2004; Silk, Dahl et al., 2007). Laboratory measures offer strengths over questionnaire data, including a controlled environment, precise measurement, and access to on-line processes. However, it is difficult to design laboratory tasks that effectively induce negative emotion in older children and adolescents given ethical constraints and given that the things that youth care most about, such as their peers, are usually not present. These tasks are necessarily limited in ecological validity and may lack generalizability because participants do not have the same control over the situation or access to typical coping resources as in their everyday environment. Although observational emotion induction tasks have often been used in studies of emotion regulation with infants and younger children, the procedures employed, such as barrier to or delay of an attractive toy, receipt of a disappointing toy, challenging puzzle tasks, arm restraint, the still-face procedure, or maternal separation, are generally not effective at inducing significant negative emotion for older children and adolescents. More ecologically valid tasks, such as interactions involving peer confederates (i.e., Hubbard et al., 2004) are promising but present daunting logistical challenges. On the other hand, children's retrospective reports of emotional experiences are limited by memory biases associated with retrospective reporting of emotional behavior (e.g., Stone et al., 1998), such as the tendency to recall the most intense and most recent experiences (Fredrickson, 2000). They also fail to tap into the "hot cognition" that occurs during real-life emotional situations, in which rational and analytical cognitive processes can be hijacked by emotional reactions (Abelson, 1963). Contextual details (such as who was present when an emotion was experienced, or how their presence effected the experience) may be easily forgotten. Finally, approaches are needed that examine emotional responses across multiple situations to allow for generalizability and that allow for examination of the temporal course of emotions.

An Ecological Momentary Assessment Approach to Child and Adolescent Depression

The Ecological Momentary Assessment (EMA) approach addresses many of these limitations by "catching" emotions as they are occurring under natural conditions in daily life. EMA is an ecologically valid method of gathering representative real-time data on emotion and behavior in natural environments through the use of signaling devices (Hormuth, 1986). EMA (also sometimes referred to as experience sampling) methods have been used to examine links between affective functioning and symptoms of depression in non-clinical samples of youth (Adam, 2006; Larson et al., 1990; Silk et al., 2003). However, the current study is the first to systematically apply these methods to investigate emotional dynamics in the natural environments of clinically depressed youth.

EMA addresses the limitations in emotion research with older children and adolescents described above by (1) providing access into emotions experienced in real-world contexts

during developmentally and socially relevant events, (2) circumventing memory biases associated with retrospective recall, (3) reflecting the motivations and choices of youth outside of the laboratory context, when they can choose their own contexts and activities, (4) providing information about social contributors to emotional experience, such as involvement of peers or parents (i.e., a depressed adolescent may show greater negative emotion with parents than when interacting with peers), (5) providing greater generalizability of emotional experience, and (6) providing information about change and variability in emotional experience over time. These advantages are described in greater detail below.

Emotional Dynamics of Child and Adolescent Depression

The EMA approach has advantages over traditional methods in measuring emotional dynamics. Emotional dynamics have been described by Thompson (1990) as parameters that reflect the intensive and temporal features of emotional responses. EMA can provide detailed information about the intensity, timing, and variability with which negative emotions are experienced in daily life. EMA studies in community samples have shown that greater intensity and lability of negative emotions are associated with elevated depressive symptomatology (Larson et al., 1990; Silk et al., 2003; Whalen, Jamner, Henker, & Delfino, 2001). For example, in a classic EMA study using pager methods, Larson et al. (1990) found that 5th through 9th graders who were higher in depressive symptoms reported more negative affect, lower energy, and greater variability in negative affect than adolescents lower in depressive symptoms. Silk et al. (2003) examined changes in intensity ratings from the peak negative emotion in the past hour to the current negative emotion (controlling for time elapsed) and strategies used to regulate emotion in early and mid-adolescents. Findings indicated that adolescents who were less effective at downregulating negative emotions and who used avoidant and ruminative emotion regulation strategies were higher in depressive symptoms.

We are aware of only one study that has used EMA methods with clinical samples of depressed adolescents. In this study, which included only 7 adolescents in an episode of MDD, bipolar disorder, or dysthymia, Merrick (1992) found that adolescents with a current mood disorder reported higher levels of sadness and greater fluctuations in emotion than normal controls. The present study sought to build upon these findings by investigating emotional dynamics in a larger clinical sample of depressed children and adolescents.

We also sought to take advantage of EMA's utility in measuring the relative balance of negative and positive emotions. This is important because it may be the combination or patterning of negative and positive emotions in relation to each other, rather than the absolute value of either, that is most associated with psychological adjustment (Fredrickson & Joiner, 2002; Fredrickson & Losada, 2005; Schwartz, 1997). For example, Frederickson and Losada (2005) reported data showing that a specific ratio of positive to negative emotion (2.9:1) was associated with better psychological adjustment in adults. EMA provides an opportunity to extend this work on affective balance to child and adolescent depression.

The Social Context of Child and Adolescent Depression

Additionally, one of the most important advantages of the EMA approach is the ability to assess the influence of the social context on emotional experience. Detailed information can be obtained about emotional experience during specific activities and in the presence of specific companions. This is critical because emotions are deeply embedded within social contexts (Morris, Silk, Steinberg, Myers, & Robinson, 2007; Zeman, Cassano, Perry-Parrish, & Stegall, 2006). Although we know little about how the social context contributes

to the experience of emotion in child and adolescent depression, social contextual differences in the expression and experience of emotions have been shown in healthy youth (Zeman & Shipman, 1998). It is likely that family and peer settings serve as important contexts to influence depressed youths' emotions. Time spent alone is also a potential contributor, as EMA studies of typically developing adolescents consistently show that time spent alone is experienced as more negative than time spent in the company of others (Larson, 1990; Larson & Csikszentmihalyi, 1978; Schneiders et al., 2007). In their small study of youth with mood disorders, Merrick (1992) found that, like the controls, mood disordered youth reported the greatest sadness when alone and the least sadness when with their friends. Larson et al. (1990) found that while adolescents higher in depressive symptoms did not actually spend more time alone than their peers, they were more likely to report wanting to be alone when they were in the presence of their families. Research conducted with adults, however, suggests that depressed individuals' emotions may be "insensitive to context" (Rottenberg, Gross, & Gotlib, 2005). In other words, depressed individuals may not "tune" their emotion to their present context. This study will investigate whether depressed youths' emotions vary when they are with parents, peers, and alone.

Pubertal Development and Child and Adolescent Depression

An additional factor that may be important to consider in understanding depressed youths' emotional experience is pubertal maturation. Puberty has an important impact on risk for depression, as rates of depression increase with puberty, particularly for girls (Angold & Costello, 2006). This may be associated with hormonal (Angold, Costello, Erkanli, & Worthman, 1999), neural (Nelson, Leibenluft, McClure, & Pine, 2005), and/or relative timing effects of puberty (Ge, Conger, & Elder, 1996), and the mechanisms underlying the relationship between puberty and depression are not clearly understood. Angold, Costello, and Worthman (1998) found that rates of depression increased in mid-puberty (Tanner stage 3), and that Tanner stage (Tanner, 1962) was a better predictor of depression onset than pubertal timing. We therefore test whether the social and emotional dynamics of depression differ for depressed youth before and after mid-puberty using Tanner staging by medical examination.

EMA and Treatment Course

Emotion research in clinical samples of youth has the potential to inform treatment approaches (Suveg, Southam-Gerow, Goodman, & Kendall, 2007). The extended sampling period of EMA can advance this agenda by facilitating an investigation of patterns in daily emotional functioning over weeks to months in ways that can track functional improvements and response to treatment. The ultimate goal of treatments for affective disorders is to improve emotional functioning in the daily lives of patients. However, clinicians rely on retrospective reports of these improvements by interview or questionnaire. Not only does this open up the possibility for reporting bias, but this also makes it difficult to have precision in understanding the timing of these changes and how they specifically track with aspects or phases of treatment.

The use of EMA permits an objective charting of the trajectory of affective changes with treatment in ways that may help to determine aspects of emotionality or emotion regulation that could predict or mediate treatment response in child depression. This could be relevant to antidepressant treatment, which has been hypothesized to reduce reactivity to emotional stimuli (Sheline et al., 2001), as well as cognitive behavioral therapies which are hypothesized to teach children skills for regulating emotions (Southam-Gerow & Kendall, 2002). Ultimately, understanding how affective functioning in the social context changes across treatment may lead to improvements in treatments for child affective disorders by helping us understand how and when treatments influence emotional functioning. This is

particularly important as, even with psychotherapy and SSRI treatment, approximately 40% of youth do not show an adequate clinical response (Brent et al., 2008).

The Current Study

The present study used a new cell phone EMA methodology in a group of youth with current Major Depressive Disorder to examine the daily emotional dynamics of child and adolescent depression. We developed the cell-phone EMA protocol for the present study to make EMA methods more feasible for studies that include younger children with mental health problems. We hypothesized that depressed youth would experience more intense and labile anger, sadness, and nervousness than normal controls, as well as higher global negative affect (NA) and a lower ratio of positive to negative affect. We also hypothesized that depressed youth would spend more time alone and report more sad, angry, and nervous emotion and global NA when alone, with peers, and with family than normal controls. We predicted that the differences in emotional dynamics and social context between depressed youth and normal controls would diminish as depressed youth progressed in an 8 week course of treatment. Finally, we hypothesized that pubertal development would influence the emotional and social dynamics of depression, with differences in emotional dynamics and social context between depressed youth and the comparison group more pronounced among pubertally mature youth.

Method

Participants

This report includes data from 79 youth participating in a longitudinal study of neurobehavioral factors in pediatric affective disorder (see Birmaher et al., 2000). Participants (48 female) ranged in age from 7–17 years (M = 12.60, SD = 2.75). Participants were in a current episode of Major Depressive Disorder (MDD; n = 47) or were no psychopathology controls (CON; n = 32) considered to be at low risk for depression based on family history, as described below. Consistent with epidemiological reports of comorbidity rates (Kessler, Avenevoli, & Merikangas, 2001), 72.3% of participants with depression had a comorbid anxiety disorder (Separation Anxiety Disorder, Generalized Anxiety Disorder, and/or Social Phobia). Participants were 89% European-American, 7% African-American, 3% Hispanic, and 1% Biracial.

Inclusion Criteria

MDD youth met diagnostic criteria according to DSM-IV (American Psychiatric Association, 1994) classification for Major Depressive Disorder. CON youth were required to be free of any lifetime psychopathology. In addition, they were required to have no first-degree relatives with a lifetime episode of any mood or psychotic disorder; no second-degree relatives with a lifetime history of childhood-onset, recurrent, psychotic, or bipolar depression or schizoaffective or schizophrenic disorder; and no more than 20% of second-degree relatives with a lifetime episode of MDD.

Exclusion Criteria

Since the youth in this study were originally recruited to participate in a broad set of biological protocols (see Birmaher et al., 2004), the following exclusionary criteria applied at the time of the initial interview: (1) the use of any medication with central nervous system effects within the past 2 weeks; (2) significant medical illness; (3) extreme obesity (weight greater than 150% of ideal body weight) or growth failure (height or weight below the third percentile); (4) IQ of 70 or less; (5) inordinate fear of intravenous needles (because of the need to draw blood for biological assays); and (6) specific learning disabilities. Youth with

depression were also excluded if they had schizophrenic, schizoaffective, or bipolar disorders.

Procedures

Both MDD and CON youth were participants in a larger longitudinal study of pediatric affective disorder. The study was approved by the University's Institutional Review Board. Participants were recruited from three sources: (1) community advertisements, (2) inpatient and outpatient clinics at a major medical center, and (3) referrals from other research studies. Youth and their parents were required to sign assents and informed consents, respectively. Structured diagnostic interviews were administered to establish lifetime and present youth psychiatric diagnoses and familial history of affective disorder. Qualifying participants were invited to participate in a multifaceted protocol that included: (1) for MDD participants, an 8-week non-randomized open treatment protocol with a Selective Serotonin Reuptake Inhibitor (SSRI [citalopram 10–40mg, escitalopram 5mg, or fluoxetine 5–25mg]; $n = 12$), Cognitive Behavioral Therapy (CBT; $n = 14$), or both ($n = 19$); (2) for all participants, a visit to the neurobehavioral laboratory during the baseline week of the study including physical exam by a pediatrician or research-trained nurse; and (3) for all participants, a home assessment protocol that included measures of emotional and social functioning in the natural environment, collected in 5 four-day blocks over the 8-week course of the study (weeks 0, 1, 3, 5, 7). The focus of this report is on data collected through the home assessment protocol. Only 4% of participants in the larger study declined participation or dropped out of the EMA protocol. All participants in the EMA protocol provided sufficient data to be included in analyses.

Instruments

Structured diagnostic interviews—Each youth and his or her parent(s) were interviewed to determine the youth's psychiatric history using the Schedule for Affective Disorders and Schizophrenia in School-Age Children—Present and Lifetime version (K-SADS-PL, Kaufman, Birmaher, Brent, & Rao, 1997). Parents and youth were interviewed separately, with clinical interviewers integrating data from both informants to arrive at a final diagnosis. To ascertain familial loading for mood disorders for CON youth, parents were interviewed using the Structured Clinical Interview for the DSM-IV (Spitzer, Williams, Gibbon, & First, 1990). Other adult first-degree and second-degree relatives were assessed indirectly using a modified version of the Family History Interview (Weissman et al., 1986), with the youth's parent(s) and other available relatives serving as informant(s). All interviews were carried out by trained BA- and MA-level research clinicians. Inter-rater reliabilities for diagnoses assessed during the course of this study were kappas ≥ 0.70. The results of the interview were presented at a consensus case conference with a child psychiatrist, who reviewed the findings and preliminary diagnosis and provided a final diagnosis based on DSM-IV criteria.

Pubertal status—Participants received a physical examination by a pediatrician or research-trained nurse to determine pubertal status by Tanner staging (Tanner, 1962). Consistent with the previously established approach by our research group (Forbes, Williamson, Ryan, & Dahl, 2004), participants in Tanner Stages 1 and 2 based on breast/gonad development were classified as pre-to-early pubertal and participants in Tanner Stages 3, 4, or 5 were classified as mid-to-late pubertal. Pubertal status data were unavailable for four participants.

Ecological Momentary Assessment

EMA Protocol—All participants completed an EMA protocol designed to provide real-time data on behavior, emotion, and social context in the child's natural environment. Through pilot testing (Axelson et al., 2003), we developed a cellular phone methodology that allowed us to maximize accuracy of reporting by allowing for probes for unclear responses and was more manageable for younger and symptomatic participants than methods requiring extensive writing. The regular contact with callers also provided promising preliminary data regarding the ability to keep participants engaged in the protocol.

Participants were given modified, answer-only, cellular telephones on which they received calls from a trained interviewer for a total of 5 four-day blocks, Friday through Monday. Each participant was called by 3–4 BA level interviewers who rotated shifts, most of whom the participant had not met in person. The study included multiple school districts throughout Western Pennsylvania; thus, it was not feasible to acquire permission for in-school sampling. The sample frame that worked best was starting Friday after school through the following Monday evening and turning off the phones during school times on Monday. This structure allowed us to sample the intervals of time when freedom and behavioral choice are most variable (after school and weekends) as well as some behavior within the structure of the school schedule for comparison. This schedule also captured the emotional space of anticipating the weekend (usually a positive time for children) and Sunday night when kids may reflect back over the week or worry about school the next day. Calls were made at the baseline week (0), following the 1st week of treatment (week 1), then at biweekly intervals for the remainder of the study (weeks 3, 5, 7). The participants were telephoned a total of 12 times between 4 p.m. Friday and 10 p.m. Monday each week with a total of 60 calls for the entire study. No contact was made during school hours on Monday or between the hours of 10. p.m. and 11 a.m. any day. If the participant did not answer on the first attempt, the call was made again after 10 minutes. If a participant was awakened by the call, he or she was offered a few minutes to wake up and was then called again. Participants were told that information obtained from the phone interviews would remain confidential (except in cases where the participants revealed imminent danger to self or others, such as child abuse or suicidality). Information from EMA calls was not shared with parents or therapists. Participants were also given the opportunity to move to a more private area before beginning the interview, if desired. Participants were compensated $35 each week, with the opportunity to earn a $5–$15 bonus for completing a high number of calls. The bonus schedule was as follows: $15 for missing 0–1 calls; $10 for missing only 2 calls; and $5 for missing only 3 calls. No bonus was given if 4 or more calls were missed. Each call consisted of a brief structured interview to evaluate current behavior, affect, and social context. The present report focuses on affect ratings and social context information.

Emotion ratings—At each call, participants were asked to rate their current emotion on a subset of 5-point scales from the Positive and Negative Affect Schedule for Children (PANAS-C; Laurent et al., 1999). Ratings for four negative emotions ("sad", "angry", "nervous", and "upset") and four positive emotions (happy, joyful, excited, energetic) were summed to create global indices of positive and negative affect. A ratio of global PA to NA was also computed by dividing global PA by global NA. For some analyses, week totals were created by averaging responses across assessment weeks. As in previous EMA studies (Larson et al., 1990; Merrick, 1992; Silk et al., 2003), lability scores were calculated for global NA and discrete negative emotions by calculating the standard deviation of each emotion across calls.

Social context—Social context variables were assessed at each call. Participants reported on their current activity, location, and social companion. Open ended responses about activities and companions were coded based on a coding system developed by Silk et al. (2003) and adapted for the present study. Reliability coefficients for activity and companion variables on a subset of 100 double-coded calls ranged from $\kappa = .85–.98$. The present report focused on the following five categories of activities that were of theoretical interest: (1) socializing with friends (i.e., talking with or interacting with friends), (2) socializing with family (i.e., talking with or interacting with one or more family members), (3) recreation (i.e., watching TV or movies, listening to music, playing video or computer games, athletics), (4) school related (i.e., homework, school-related computer work, extracurricular activity) and (5) doing nothing (i.e., "nothing," "just sitting here"). Companion analyses focused on time spent with family, peers, or alone. Neither categories nor companions were mutually exclusive, as participants could be engaged in simultaneous activities or with multiple companions.

Analytic Plan

Data on momentary emotion were analyzed using repeated measures linear mixed effects models to account for the nesting of assessments within participants and across time. Models were tested for global NA, the discrete emotions "anger," "sadness," and "nervous," and the PA:NA ratio. All mixed effects models included participant as a random effect and call number as a repeated measure. Fixed effects were included for week to test for the effects of change over time, and diagnostic group, as well as a week by diagnostic group interaction. We also included a main effect for pubertal status and the interaction between pubertal status and diagnostic group. Covariates were included for child race, gender, and age. We chose not to test three way interactions due to concerns about statistical power. Significant interaction effects were probed using post-hoc Least Significant Difference (LSD) tests of marginal means.

We examined lability or variability of emotions using repeated measures ANOVAs testing group differences and changes over time in the weekly standard deviation (SD) of each emotion. Because one would expect the SDs of negative emotions to be higher for the MDD than the LRN group if the means are higher (as hypothesized), we examined whether the difference in SDs was significant above and beyond mean differences in negative emotion by including mean levels of negative emotion as a covariate (i.e., controlling for mean sadness in the model examining lability of sadness). Between-subjects effects were included for diagnostic group and pubertal status, as well as interactions between diagnostic group and week and diagnostic group and pubertal status. Again, covariates were included for child race, gender, and age. The sphericity assumption was not met so the Huynh-Feldt correction was applied.

Group differences in social context variables were also explored using repeated measures ANOVA. Because these data were categorical (e.g., with or without peers), proportions were calculated for each week indicating the proportion of completed calls for that week in which a particular social companion or activity was endorsed. Week was treated as a repeated measure, with between-subjects effects for diagnostic group and pubertal status, as well as the interaction between diagnostic group and week. Again, covariates were included for child race, gender, and age. We further compared emotion across social contexts by conducting repeated measures ANOVAS comparing mean emotion scores for each social context. Separate ANOVAS were conducted for social companions and social activities. Diagnostic group was treated as a between subjects effect. Significant context effects were further probed using post-hoc Least Significant Difference (LSD) tests.

Results

Feasibility

Analyses indicate that the method was feasible. The average call time was 3.78 minutes. The median rate of call completion was 55 out of 60 calls (92%), a rate comparable or superior to compliance reported in EMA studies using alternative methodologies (Csikszentmihalyi & Larson, 1992; Larson, Moneta, Richards, & Wilson, 2002; Stone et al., 1998). Missing data because of equipment problems or cell phone service disruption was rare (0.7% of the cases).

Preliminary Analyses

Demographic variables are shown in Table 1. There were no diagnostic group differences in gender, age, or pubertal status. However, participants in the CON group were more likely to be European American and had higher SES scores than in the MDD group. Because SES data were missing for 12 participants, we choose to covary race (European American vs. non-European American) but not SES in the main analyses reported below. However, analyses were also replicated in the subsample of participants with SES data controlling for SES.

We also examined whether there were developmental differences in momentary emotional experience. Bivariate correlations indicated that there were no significant relations between age and ratings of intensity or lability of sadness, anger, nervousness, or global NA (all *p*'s > .05); however there was a trend for older children to have a lower ratio of PA:NA ($r = -.20$, $p = .05$). Because of our large age range, we included age as a covariate in analyses.

Momentary Emotion

Intercorrelations among indicators of momentary emotional experience are presented in Table 2 and mixed effects models examining predictors of momentary emotional experience are summarized in Table 3. Main effects for diagnostic group emerged in predicting global NA, sadness, anger, nervousness, and the PA:NA ratio. Post-hoc LSD tests of marginal means revealed that MDD youth experienced higher levels of global NA, sadness, anger, and nervousness than CON youth, and a lower ratio of PA:NA (see Table 4). For global NA, sadness, and anger, this main effect was qualified by a diagnostic group X week interaction. As shown in Figure 1, global NA decreased over time for the MDD group (coefficient = −.02, $p < .001$) but not the CON group (coefficient = .01, $p = .09$, $d = .20$). There were also decreases across time for the MDD group in sadness (coefficient = −.03, $p < .001$) and anger (coefficient = −.02, $p < .001$), while sadness (coefficient = .01, $p = .19$; $d = .25$) and anger (coefficient = .00, $p = .29$; $d = .18$) did not decrease across time for the CON group (Figure 1).

As also shown in Table 3, diagnostic group interacted with pubertal status in predicting all five indices of momentary emotion. Among CON's, negative emotions decreased with pubertal status (global NA *coefficient* = −.08, $p < .001$; sadness *coefficient* = −.08, $p < .01$; anger *coefficient* = −.05, $p < .05$, nervous *coefficient* = −.08, $p < .001$). However, among the MDD group, negative emotions either increased with pubertal status (global NA *coefficient* = .04, $p < .05$, $d = .17$; sadness *coefficient* = .09, $p < .001$, $d = .18$; anger *coefficient* = .05, $p < .05$, $d = .12$) or did not change with pubertal status (nervous *coefficient* = .01, $p = .68$, $d = .11$). Conversely, the PA:NA ratio increased with pubertal status for normal controls (*coefficient* = .37, $p < .001$) and decreased with pubertal status for youth with MDD (*coefficient* = −.64, $p < .001$, $d = .46$).

A between-subjects effect for diagnostic group indicated that MDD youth had greater lability than controls in global NA ($F = 8.12$, $p < .01$), sadness ($F = 16.67$, $p < .001$), and anger ($F = 3.91$, $p = .05$; see Table 4). Tests of within-subjects effects revealed that these main effects were qualified by diagnostic group by week interactions for lability of global NA ($F = 2.65$, $p < .05$, partial eta$^2 = .05$), sadness ($F = 3.95$, $p < .01$, partial eta$^2 = .07$), and anger ($F = 4.67$, $p < .001$, partial eta$^2 = .08$). Post-hoc within-subjects contrasts within each diagnostic group revealed linear decreases across time for MDD youth in lability of global NA ($F = 3.12$, $p < .05$), sadness ($F = 8.26$, $p < .01$), and anger ($F = 14.68$, $p < .01$). CON youth showed no significant changes across time in lability of global NA or anger, and actually showed significant increases over time in lability of sadness ($F = 5.11$, $p < .05$).

Social Activities and Companions

Aggregate proportions of time in selected social contexts are presented in Table 5. In order to better understand differences in emotional experiences across contexts, we examined whether diagnostic groups differed in their social contexts. Between-subjects effects for diagnostic group emerged for time spent alone ($F = 4.66$, $p < .05$) and with family ($F = 7.84$ $p < .001$), but not with peers ($F = .24$, $p = .63$). Post-hoc LSD tests of marginal means revealed that MDD youth spent more time alone and less time with their families than CON youth (Table 5). There were no within-subjects effects of week or interactions with week on social companions or activities. There were also no between-subjects effects for diagnostic group for social activities.

A repeated measures ANOVA revealed that youth differed in levels of negative emotion experienced within social context ($F = 5.83$, $p < .01$; partial eta$^2 = .14$). Post hoc LSD tests indicated that both MDD and CON youth reported higher NA when alone or with family than when with peers. Although this pattern was the same for MDD and CON youth, mean levels of NA were higher for DEP youth in all three contexts ($F = 12.79$, $p < .001$; partial eta$^2 = .16$). Repeated measures ANOVA's for sadness ($F = 3.33$, $p < .05$; partial eta$^2 = .05$), anger ($F = 4.71$, $p < .01$; partial eta$^2 = .06$), and the PA:NA ratio ($F = 49.45$, $p < .001$; partial eta$^2 = .41$) also revealed differences in emotion across context. Specifically, post-hoc LSD tests revealed that MDD and CON youth were less sad with peers than when alone and less angry with peers than when alone or with family. Post-hoc tests also revealed that youth reported the highest ratio of PA:NA when with peers, followed by family members, and the lowest ratio when alone. Again, MDD youth were more sad ($F = 15.49$, $p < .001$; partial eta^2 $= .18$) and angry ($F = 14.31$, $p < .001$; partial eta$^2 = .17$), and reported a lower PA:NA ratio ($F = 21.46$, $p < .001$; partial eta$^2 = .24$) than CON youth across all three companion contexts. There were no differences across companion contexts in levels of nervousness ($F = .40$, $p = .68$; partial eta$^2 = .01$).

Similarly, repeated measures ANOVAs for activities revealed differences in global NA ($F = 3.13$, $p < .05$; partial eta$^2 = .07$), sadness ($F = 2.97$, $p < .05$; partial eta$^2 = .07$), and the ratio of PA: NA ($F = 3.86$, $p < .05$; partial eta$^2 = .09$) experienced during different types of activities, although differences were not found for anger ($F = 1.79$, $p = .15$; partial eta$^2 = .04$) or nervousness ($F = .29$, $p = .83$; partial eta$^2 = .01$). Specifically, both MDD and CON youth reported higher global NA when "doing nothing" then when socializing with families. Youth were sadder when doing nothing than when socializing with families, socializing with friends, and engaging in recreational activities. The ratio of PA:NA was higher when socializing with friends than when engaged in recreational activities or doing nothing, and was higher when socializing with family than when doing nothing. There were no differences in the ratio of PA:NA when socializing with friends vs. family. As with social companions, mean levels of global NA ($F = 7.25$, $p < .01$; partial eta$^2 = .16$), anger ($F = 5.32$, $p < .05$; partial eta$^2 = .12$), and sadness ($F = 2.97$, $p < .05$; partial eta$^2 = .14$), were

lower and the PA:NA ratio higher ($F = 16.28$, $p < .001$; partial $eta^2 = .29$) in the MDD relative to the CON group across all activities.

Discussion

The cell-phone EMA approach developed for this study proved to be feasible to use in a young clinical population and revealed several ways in which momentary emotional experience differed between depressed youth and their peers. Compared to normal controls, depressed children and adolescents experienced more intense negative emotions. Consistent with Silk et al. (2003), this included sadness, anger, and nervousness, as well as an index of global negative affect, suggesting a general increase in negative emotions, as opposed to a pure increase in sadness. We also found greater lability of negative emotions, including sadness, anger, and global NA, in depressed youth, even controlling for mean intensity of emotions. These findings validate reports from EMA studies of depressive symptoms in community samples of youth pointing to increased variability in negative emotion as a key feature of the daily experience of child and adolescent depression (Larson et al., 1990; Merrick, 1992; Silk et al., 2003).

In addition to increased negative emotion, we found alterations in the balance of positive and negative emotion in depressed youth. The ratio of positive to negative affect in normal controls was 3.0:1.0, which is above the critical 2.9:1.0 ratio that Frederickson and Losada (2005) have reported previously as associated with optimal psychological adjustment in adults. In contrast, depressed youth fell well below that ratio at 2.0:1.0. This finding illustrates the importance of investigating disruptions in positive emotion in child and adolescent depression as an important target for future research (Forbes & Dahl, 2005). Surprisingly, there were no changes in this ratio throughout treatment, raising questions about the possibility of targeting the ratio or balance of positive and negative emotion as a future goal for treatment research.

There were a few differences in social contexts across diagnostic groups. First, in contrast with Larson et al.'s (1990) findings with youth high in depressive symptoms, clinically depressed youth spent more time alone than their non-depressed peers—42% of their time compared to 29% for healthy controls. This is far greater than the 25% time alone estimated to be typical for children and adolescents (Larson, 1990). This is important because of the potential for solitary time to contribute to rumination and negative thoughts in depressed youth. Second, depressed youth spent less time with their family members--37% compared to 54% for their non-depressed peers. As a large body of evidence suggests that the family environments of depressed youth are less warm and supportive than those of non-depressed youth (see Sheeber et al., 2001), depressed youth may find family time less rewarding than other children.

This study revealed consistent differences in emotional experience depending on social context, which were similar for depressed and healthy youth. Youth showed more negative emotion when they were alone than when they were with their peers or family members. Discrete emotions analysis revealed the lowest levels of anger and sadness when in the peer context--even for depressed youth. For both groups, the balance of positive to negative emotion was most strongly tipped toward positive emotion when youth were with their peers, followed by family members, followed by being alone. Differences in the PA:NA ratio based on social companions were especially striking, with companionship accounting for 41% of the variance in the PA:NA ratio. This finding highlights the importance of considering social context in studying youths' emotions, as youths' emotions appear highly intertwined with their social companions. Several differences also emerged in momentary emotion across types of daily activities. As expected, youth were most negative when they

reported that they were “doing nothing.” This was most clear in the case of sadness, where youth reported higher levels of sadness when “doing nothing” compared to socializing with family or friends or engaging in recreational activities. On the other hand, the ratio of positive to negative emotion was strongest when socializing with friends compared to engaging in recreational activities and doing nothing.

This pattern of findings suggests that depressed and typical youth are feeling their best when with their peers and feeling their worst when bored and alone. This replicates Merrick’s (1992) finding that mood disordered youth, like controls, were most sad when alone and least sad when with their peers. Thus, in contrast to predictions from the insensitivity to context theory of depression (Rottenberg et al., 2005), depressed youth do appear to “tune” their emotional experience to their present context. However, although depressed youth showed the same pattern of emotional experience as no psychopathology controls, they differed in the *intensity* of emotional experience across social contexts. Depressed youth had more negative emotion and a lower ratio of positive to negative emotion than controls regardless of whom they were with or what they were doing. These findings suggest that perhaps there is not a qualitative difference in the types of activities enjoyed by depressed children and adolescents and their peers, but just a quantitative difference in the level of emotion experienced during these activities.

Our findings also suggest that puberty may influence emotional dynamics differently among depressed and typically developing youth. While typically developing youth further along in puberty had a tendency to report lower levels of negative emotion and a higher ratio of positive to negative emotion than their pre-and early pubertal peers, depressed youth further along in puberty reported higher levels of global negative emotion, sadness, and anger and a lower ratio of positive to negative emotion than their pre-or early pubertal counterparts. Thus, differences in negative emotion between depressed youth and no psychopathology controls were amplified with increasing pubertal status. This finding remained after controlling for participants’ age, suggesting that the effect is puberty-specific. This may be related to puberty-specific changes in sensitivity to social-emotional stimuli (Nelson et al., 2005; Silk et al., 2009). Although the mechanisms are not clearly understood, factors contributing to increased negative emotionality and/or difficulty regulating negative emotions appear to be exacerbated by puberty in youth vulnerable to depression.

We found that diagnostic group differences in momentary negative emotion decreased over the 8 week treatment period. Depressed youth showed less global negative emotion, sadness, and anger over time compared to their baseline scores. These changes occurred in both the intensity and lability of global NA, anger, and sadness. There were no changes in depressed youths’ ratio of positive to negative emotion or the amount of time spent with family or alone. These findings are preliminary, as this study was an open treatment trial. However, we believe these preliminary findings highlight the potential utility of this method for tracking mediators of treatment response in future research with randomized clinical trials, and in revealing domains that do not change with treatment and may thus need to be more effectively targeted. For example, if replicated, these findings could suggest that treatments for depression may need to do more to increase positive emotions and decrease solitary activity.

Although this is the first report, of which we are aware, to collect emotion ratings from a clinically depressed sample of youth, previous EMA reports of community samples using a variety of methods show that youth generally report low intensity and limited ranges of negative emotion (Schneiders et al., 2007; Silk et al., 2003; Weinstein, Mermelstein, Hedeker, Hankin, & Flay, 2006). In the present study, depressed youth reported higher intensity and lability of all types of negative emotion than normal controls; these findings

were shown to generalize across all contexts examined, to be of moderate to large effect based on Cohen's (1988) effect size estimates, and to change with treatment. Despite these group differences and changes over time, the absolute intensity of negative emotions reported by depressed youth was surprisingly low. For example, mean pretreatment global NA in the depressed group was only 1.43 on a 1 to 5 scale. Thus, although depressed youth are more negative than their peers, they do not report themselves to be as negative as one might expect given clinical anecdotes of extreme sadness and emotional dysfunction.

Memory biases and other cognitive/affective distortions may help to explain these unexpected findings. Known "peak" and "end" biases make individuals more likely to remember their most intense and most recent experiences (Fredrickson, 2000). Overgeneralized negative memory biases may also be operating to make depressed youth retrospectively recall their emotional experiences as having been even more intensely negative than they were experienced in real time. This is an intriguing possibility as evidence has been found for an overgeneralized autobiographical memory bias in depressed adults (Williams, 1996). Extending this work to adolescents, Park, Goodyer, and Teasdale (2004) have found evidence of increased negative overgeneral memories in depressed adolescents following a rumination induction compared to controls and other psychiatric inpatients. This finding, together with our data, suggests that perhaps depressed adolescents experience events as only mildly negative in the moment, but, through processes such as prolonged rumination, the affective quality associated with these events is amplified and generalized to other experiences, leading to a more pervasive negative memory of the day's events. This more negative picture in turn might be reported upon to clinicians and recalled by the depressed adolescent as the reality of his or her experience. Thus, it is possible that depressed youth may be engaging in a form of "affective distortion" similar to the well documented cognitive distortions of depression (e.g., Hankin, Abramson, Miller, & Haeffel, 2004). This is consistent with data from a recent EMA study showing that adults with MDD show retrospective intensification of negative emotion when comparing retrospective accounts of negative emotion for a week with real-time EMA accounts (Ben-Zeev, Young, & Madsen, 2009). Future research using EMA methods is needed to replicate and further explore these findings, which could have important clinical implications. In particular, tools to provide youth with a more realistic understanding of their daily emotional experience could provide helpful clinical feedback to improve treatment response.

Strengths and Limitations

Several limitations of the present study should be noted. First, the sample was relatively small, limiting our power to focus on other variables of interest (i.e., gender). Second, because our participants came from a variety of school districts, and because of concerns with distracting children during school hours, we were not able to obtain permission to collect information from children during the school day. We sampled children after school and in the evening on two weekdays and also on Sunday evening in an attempt to tap into some of the emotions surrounding the school day; however, there may be important social and emotional experiences that occur within the school environment that this method is not able to easily assess. Depressed youth in this study received heterogeneous treatment that could have consisted of cognitive behavioral therapy, one of several SSRI medications, or both. Furthermore, participants were not randomized to treatment. We recommend the use of EMA in future research with larger samples in the context of randomized clinical trials to better elucidate affective changes involved in treatment for child and adolescent affective disorders.

This study also has several strengths. It utilized an innovative, intensive cell-phone EMA protocol to provide more ecologically valid data about social and emotional functioning in daily life. The study advances previous work in this area by focusing on a rigorously

diagnosed clinical sample of youth with depression and by utilizing an approach that provides data collected in natural home environments over an extended period of time, throughout a course of clinical treatment. It also enhances our understanding of interactions between depression and pubertal development utilizing Tanner staging obtained from physical examinations.

Findings indicate that cell phone EMA is a feasible approach with young clinical samples. Findings remained significant controlling for age, indicating that the method seems to be valid across the 7–17 year old age range. Furthermore, this approach has the potential to highlight changes that are associated with treatment and to provide information that could be clinically useful for improving the treatment of depressed youth. General advantages of the EMA approach included improved ecological validity over laboratory and questionnaire measures, elimination of retrospective reporting biases, and access to information about variability in emotions, change in emotions over time, and the balance of positive and negative emotions. We also found that the method was useful for helping us to understand the social context of emotional experience. Specific advantages of our cell phone approach included an excellent completion rate, additional monitoring of our clinical sample, the ability to explain things to youth immediately when they were confused or unclear, to prompt for more information, to repeat missed calls, and to obtain a large amount of information without requiring the participants to enter large amounts of text. However, although the use of live interviewers has several advantages, it is possible that youth may be less likely to report private or emotional experiences to another person than on an electronic device. As smartphones become widely available and increasingly familiar to young children, it would be valuable in future research to compare data obtained from human-interaction and automated cell phone EMA approaches.

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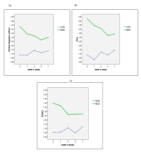

Figure 1.
Changes over Time in (a) Global Negative Affect, (b) Sadness, and (c) Anger by Group

Table 1

Sample Demographics

	CON (*n* = 32)	MDD (*n* = 47)	t/χ^2
Age	12.29 (2.72)	12.93 (2.77)	−1.02
Sex (% female)	59.4	61.7	.04
Race (%)			7.98**
European American	100	76.6	
African American	0	12.8	
Hispanic	0	6.4	
Biracial	0	2.1	
SES	46.77 (8.17)	36.37 (12.45)	3.81***
Pubertal Status (%)			.35
pre-to-early	19	20	
mid-to-late	20	35	

Note: Values are mean (SD) unless reported as percentage. Participants were classified as pre-to-early pubertal if they were Tanner stage < 3 and as mid-to-late pubertal if they were Tanner stage ≥ 3. Pubertal status data were unavailable for four participants. SES = socioeconomic status, measured by the Hollingshead Index (Hollingshead, 1975). Twelve participants were missing data on SES.

Table 2

Intercorrelations among Indicators of Momentary Emotional Experience

	1.	2.	3.	4.	5.	6.	7.	8.	9.
Intensity									
1. Global NA	1.00								
2. Sad	.87***	1.00							
3. Angry	.88***	.66***	1.00						
4. Nervous	.82***	.61***	.62***	1.00					
5. PA:NA Ratio	−.43***	−.44***	−.41***	−.24*	1.00				
Lability									
6. Global NA	.78***	.65***	.77***	.58***	−.34**	1.00			
7. Sad	.79***	.78***	.67***	.55***	−.36**	.89***	1.00		
8. Angry	.73***	.57***	.83***	.46***	−.40***	.89***	.75***	1.00	
9. Nervous	.74***	.56***	.56***	.85***	−.20	.75***	.68***	.57***	1.00

* $p \leq .05$,

** $p \leq .01$,

*** $p \leq .001$

Table 3

Summary of Fixed Effects for Mixed Effects Models of Momentary Emotion with Participant as Random Effect

	F				
	Global NA	**Sad**	**Nervous**	**Angry**	**PA:NA Ratio**
Diagnostic Group	143.88***	173.47***	9.03**	80.00***	180.29***
Week	4.48*	11.84**	.04	5.63*	1.41
Diagnostic Group X Week	21.94***	29.76***	2.23	15.67***	.07
Pubertal Status	2.83	3.15	.00	.01	1.20
Diagnostic Group X Pubertal status	21.92***	22.05***	8.69**	9.28**	197.96***
Gender	.59	6.47*	10.42**	5.90*	23.14***
Race	1.99	34.03***	1.48	6.36*	1.33
Age	.98	7.18**	5.87*	.04	28.29***

Note.

* $p < .05$;

** $p < .01$;

*** $p < .001$.

Table 4

Aggregate Emotional Dynamics by Diagnostic and Puberty Group

	CON			MDD			
	Pre/Early Pubertal	**Mid/Late Pubertal**	**All CON**	**Pre/Early Pubertal**	**Mid/Late Pubertal**	**All MDD**	**Cohen's *d* (MDD vs. CON)**
Intensity							
Angry	1.11 (.43)	1.04 (.24)	1.07 (.35)	1.27 (.70)	1.34 (.78)	1.32 (.75)	−.43[a]
Sad	1.14 (.52)	1.04 (.26)	1.09 (.42)	1.33 (.71)	1.45 (.77)	1.40 (.74)	−.46 [a]
Nervous	1.20 (.68)	1.10 (.45)	1.15 (.58)	1.20 (.59)	1.21 (.57)	1.23 (.59)	−.14 [a]
Global NA	1.15 (.39)	1.07 (.22)	1.11 (.32)	1.28 (.50)	1.35 (.53)	1.33 (.52)	−.51 [a]
PA:NA Ratio	2.84 (1.09)	3.20 (.87)	3.02 (1.00)	2.61 (1.32)	1.93 (1.06)	2.16 (1.20)	.78 [a]
Lability							
Angry	.23 (.33)	.15 (.19)	.19 (.27)	.52 (.35)	.62 (.34)	.59 (.34)	−1.30 [a]
Sad	.26 (.37)	.19 (.18)	.22 (.29)	.58 (.23)	.58 (.28)	.56 (.27)	−1.21 [a]
Nervous	.38 (.48)	.24 (.34)	.30 (.42)	.43 (.30)	.43 (.28)	.44 (.28)	−.39
Global NA	.21 (.24)	.15 (.14)	.18 (.20)	.37 (.18)	.40 (.20)	.38 (.19)	−1.03 [a]

Note: Aggregate means are across all calls. NA = Negative Affect; PA = Positive Affect. Values are mean (SD).

[a]Diagnostic group main effect was statistically significant.

Table 5

Proportions of Time in Social Contexts by Diagnostic Group

	CON	MDD	Cohen's *d*
Activity			
Soc. with friends	.04 (.04)	.05 (.07)	−.18
Soc. with family	.08 (.08)	.06 (.06)	.00
Recreation	.48 (.15)	.47 (.13)	.07
School Related	.03 (.03)	.02 (.03)	.33
Doing Nothing	.04 (.04)	.06 (.05)	−.44
Companion			
Alone	.29 (.18)	.42 (.20)	−.68 [a]
Family	.54 (.24)	.37 (.21)	.75 [a]
Peer	.18 (.11)	.19 (.17)	−.07

Note: Values are mean (SD). Soc. = Socializing.

[a] Diagnostic group main effect was significant.