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A State Space Analysis of Emotion and Flexibility in Parent-Child Interactions

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Negative emotion has been shown to reduce flexibility in cognition and behavior. We examined interpersonal flexibility during negative emotional episodes within parent-child interactions. Fifty-five mothers and early-adolescent daughters were observed during a positive discussion, a negative (conflict) discussion, and another positive discussion. Codes of moment-to-moment changes in emotion expression were used to create state space grids from which measures of emotional valence and flexibility were derived. As expected, mean flexibility was lowest during the conflict discussion when negative emotion peaked, suggesting that interpersonal flexibility decreases with increasing negative emotion. Sub-groups identified as low or high in stress were also compared. Dyads with girls reporting more stressful events showed lower flexibility during the first positive discussion. However, dyads expressing more negative emotion during the conflict discussion were also more flexible, suggesting that flexible dyadic styles permit more negative emotion. These individual difference findings are discussed in terms of the suppression versus expression of negative emotions.

Keywords: dynamic systems, emotions, flexibility, parent-child interaction, state space grids

Negative emotional states can narrow the range of cognitive and behavioral responses to environmental demands (Derryberry & Tucker, 1994; Mathews & MacLeod, 1985). However, research has almost exclusively focused on the effect of emotions on the flexibility of cognitive performance or isolated aspects of social behavior in highly controlled experimental conditions (Schultz & Searleman, 2002). Recently, this research has been extended into more naturalistic settings to examine behavioral flexibility within interpersonal relationships. Specifically, stressed couples heading for divorce (Gottman & Levenson, 1992) and parent-child dyads with externalizing children (Hollenstein, Granic, Stoolmiller, & Snyder, 2004) have been shown to exhibit more rigid (i.e., less flexible) behavior. To date, however, no study has explicitly investigated associations between negative emotions and flexibility during naturalistic interactions in typical populations. The present observational study explored these associations within one of the most emotionally intense relationships–mothers and daughters–during one of its most volatile periods–early adolescence. We report on the impact of conflict and stress on the emotional tone and flexibility of the mother-daughter dyad, using a novel method of behavioral analysis based on dynamic systems principles.

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Both negative and positive emotions have an impact on cognition and behavior. Anxiety and anger, for example, constrain the direction and focus of attention to emotion-relevant cues (Derryberry & Tucker, 1994; Mathews & MacLeod, 1985). In contrast, positive emotions elicit more malleability and scope in cognitive operations (Isen, 1987). These effects on cognition have been demonstrated by the ability to switch "mental sets" in categorization tasks (e.g., Wisconsin Card Sort) that require cognitive flexibility to adapt to the changing task demands. In these paradigms, positive emotion reduces perseveration (Dreisbach & Groschke, 2004) while negative emotional states reduce the tendency to give up unsuccessful cognitive strategies (Davis & Nolen-Hoeksema, 2000; Gasper, 2003). There is also a link between negative emotion and reduced flexibility in interpersonal behavior (Forgas, 2002; Paulhus & Martin, 1988). Gottman and colleagues have shown this link repeatedly in studies of marital interactions; distressed couples headed for divorce share more negative emotion and cannot flexibly emerge from these negative dyadic states (e.g., Gottman & Levenson, 1986, 1992; Gottman & Notarius, 2000). However, these studies have only demonstrated how couples can get stuck in particular states, not how emotion may affect the overall structure of the interpersonal playing field.

One of the best ways to evaluate the relation between expressed emotion and other variables, such as flexibility, is to manipulate the situational demands. Indeed, this kind of cross-situational comparison has been a staple of emotion research with paradigms designed to induce both positive and negative emotions (e.g., Isen, 1987; Mathews & MacLeod, 1985). An A-B-A design (i.e., positive to negative to positive mood induction), such as the still face procedure to examine infant emotional reactivity (e.g., Weinberg & Tronick, 1996), can be particularly useful for observing deviations from and returns to baseline levels of emotional valence. In the current study, we manipulated the conversational context to effect changes in emotional valence and then test for changes in the flexibility of parent-child interactions. Thus, with this design we could examine the real-time structure of interpersonal dynamics within contexts and the relative change in these dynamics as dyads adapted to situational demands across contexts.

The entry into adolescence is marked by significant increases in negative emotion, decreases in positive emotion, and increases in family conflict (Arnett, 1999; Larson & Ham, 1993; Laursen, Coy, & Collins, 1998). The entire family system must adjust to these changes, but the greatest amount of conflict has been found to occur with mothers and daughters just entering adolescence (Collins, 1990; Hill, 1988). Moreover, early adolescents are more sensitive to and experience more stressful life events than both older and younger individuals (Larson & Ham, 1993), and this is even more prominent in females than in males (Graber, 2004). From a dynamic systems perspective, parent-child dyads are stable, coherent systems, especially when engaged in emotionally charged interactions (Fogel, 1993). Whether a perturbation to the system comes from the parent (i.e., a reprimand) or from the child (i.e., a sarcastic remark), both parties must adapt and adjust behavior. For our purposes, therefore, observing mother-daughter interactions in early adolescence was ideal; the greater incidence of negative emotions, conflict, and stress affects both mother and daughter as a dyad.

The naturalistic study of flexibility has been hindered by measurement difficulties. Questionnaires and passive mood induction paradigms fail to capture the necessary temporal dynamics of flexibility and observational studies have not measured flexibility directly. Recently, however, such processes have been studied with methods inspired by dynamic systems principles that target dyadic variability (e.g. Gottman, Murray, Swanson, Tyson, & Swanson, 2002; Granic & Hollenstein, 2003; Hollenstein et al., 2004; Steenbeek & van Geert, 2005). In the present study, we use one such method, state space grids (Lewis, Lamey, & Douglas, 1999), to explore the relationship between expressed emotion and flexibility in mother-daughter dyads for several reasons: (a) this method allows the dyad to remain the unit of analysis; (b) both the structure (flexibility) and content (expressed emotion) of dyadic interactions can be viewed and measured; and (c) measures of flexibility do not rely on narrow temporal contingencies (i.e., the behavior immediately following an observed emotion), but instead are derived from the overall patterns of interaction.

A state space, broadly defined, is an idealized map of all the possible states of a system. In terms of dyadic social interaction, the state space could be comprised of all possible joint states of two individuals (the dynamic system), and a particular pattern of interaction could be depicted as a trajectory that moves within this space from state to state over time. Taking this approach to the study of dyadic emotional behavior, one can use a sequence of emotion categories to define each axis of the state space, one per dyad member. The location of the behaviors would then represent the content of emotional communication, whereas the pattern of movement across the state space would provide information about the structural dynamics (e.g., flexibility) of the dyadic interaction. State space grids are a graphical approach that quantifies observational data according to two ordinal variables that define the state space for the system. The grid is comprised of cells that represent each possible behavioral combination, and a sequence of behavioral states (a trajectory) can be plotted from cell to cell. In the present application (Figure 1), the parent's coded behavior is represented on the *x*-axis, the child's behavior on the *y*-axis, and their simultaneous or dyadic states by the cells of the grid. Any time there is a change in either person's behavior, a point is plotted in a different cell and a line is drawn from point to point representing the sequence of dyadic states. We report here on two measures of flexibility and a measure of expressed negative emotion derived from these grids.

In order to examine associations between emotional valence and flexibility, we conducted three discussions between mothers and daughters in an A-B-A sequence: positive valence, negative valence, positive valence. Negative emotional valence was evoked by having the dyads discuss an unresolved conflict that they identified as "still upsetting." We hypothesized that increased negative emotion would be associated with reduced flexibility during the conflict discussion. To explore individual differences in flexibility related to ongoing emotional issues, we also measured the amount of stress the girls were currently experiencing, with the assumption that their stress would affect the real-time dynamics of the dyadic system. We hypothesized that dyads with girls who reported a larger number of stressors would demonstrate less flexibility and more negative emotion overall.

Method

Participants

Fifty-six sixth-grade girls and their mothers were recruited to participate in a longitudinal study through newspaper ads and schools in a large Canadian city. The results reported here are based on the first wave of that study. The girls' ages ranged from 11.1 to 12.3 years ($M = 11.8$) and the mothers' ages ranged from 29.7 to 56.9 years ($M = 44.0$). Sixty-two percent of the mothers were married; 15% were single; 8% were divorced; and 15% were living with a domestic partner. The median family income was between $75,000 and $100,000 Canadian dollars per year. Seventy-three percent of the mothers were European-Canadian, 7% were Caribbean-Canadian; 6% were Asian; 4% were Native Canadian; 4% were Hispanic; and 7% reported being "other." Seventy-nine percent of the daughters were European-Canadian, 8% were Caribbean-Canadian, 6% were Asian, 4% were Native Canadian, and 3% reported being "other." Due to a technical mishap, one family's video files were lost and the sample was reduced to 55 dyads.

Procedure

All sessions were conducted in a square room with two chairs facing each other, a chair for the examiner to the side, a small table in the middle, and two shelving units in opposite corners, each containing a camera (hidden behind a mirror) and a microphone. Each chair was oriented to keep the participants facing each other, but leave an unobstructed view for the cameras. A computer in an adjacent room recorded the digital video of the interactions. The cameras could be controlled to adjust the zoom or camera angle if necessary.

Prior to videotaping, participants filled out consent forms and questionnaires for 15–30 minutes. Next, the participants began a series of three discussions interspersed by a brief word game. For the word game, the daughter was instructed to say out loud as many single words as she could think of in one minute after hearing each of three target words. The word game was intended to break up the series of discussions and to supply additional data for the longitudinal analyses (not reported here). The

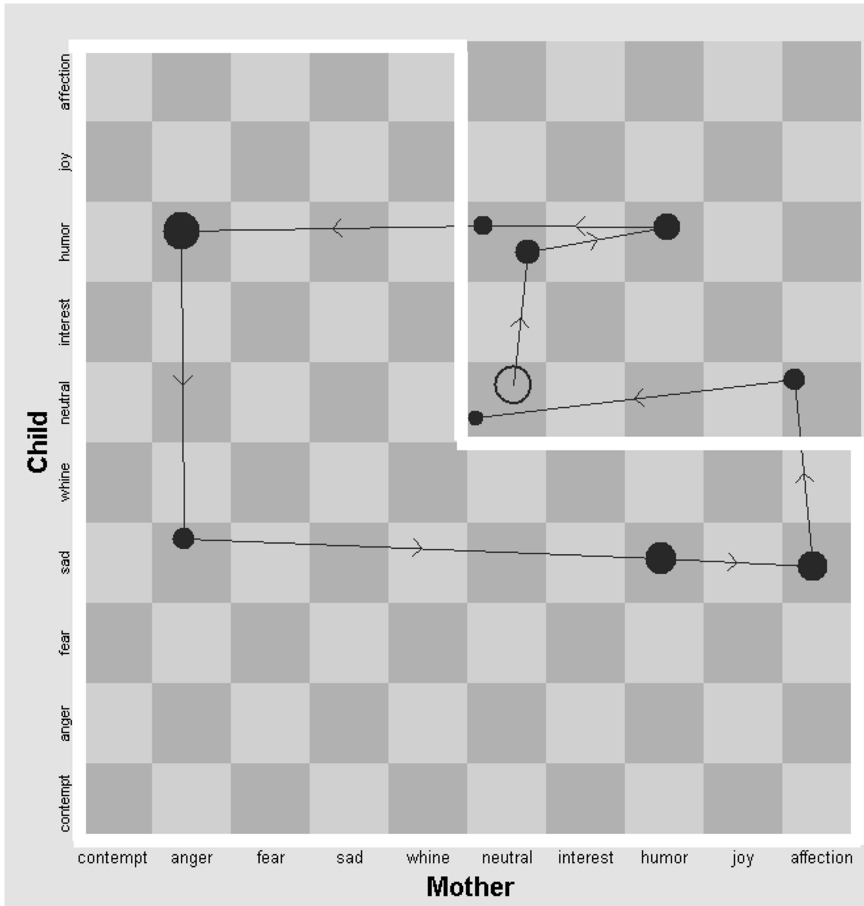

Figure 1. Example state space grid. The sequence of the mother's and daughter's expressed emotions is shown by the trajectory of connected plot points; the diameter of these points reflects the duration of each dyadic event. The outlined L-shaped area is the Negative Emotion region of the grid.

examiner left the room before the beginning of each discussion. Following the procedure, the participants were paid 40 dollars and given a 15 dollar gift certificate for a large music store.

The first and third discussion topics were positive: planning a vacation or a birthday party with an unlimited amount of money. These topics were counterbalanced across participants and were each 4 minutes long. One of the questionnaires completed initially was used to choose the topic of the second discussion–a self-reported conflict that mother and daughter identified as "still upsetting." Pilot testing revealed that four minutes was not long enough for girls and their mothers to complete the discussion. Thus, the second discussion was extended to eight minutes in duration. However, because differences in emotion or flexibility between discussions could potentially be explained by these differences in duration, the conflict discussion was split into two four-minute segments for analysis. This split also allowed us to examine differences in flexibility between the early and late portions of the conflict discussion. Analyses were run both with and without splitting the discussion and results were similar. For clarity and simplicity, only the split-discussion results are presented here. Discussion numbers were assigned as follows: Discussion 1 (vacation or birthday topic), Discussion 2a (first half of conflict discussion), Discussion 2b (second half of conflict discussion), Discussion 3 (vacation or birthday topic).

Coding Procedures

Observational codes were recorded using the Noldus Observer 5.0. Observers entered codes for each participant independently in real time, yielding two synchronized streams of continuous events. This data format is optimal for state space grids.

Each participant was coded with the Specific Affect coding system (SPAFF; Gottman, McCoy, Coan, & Collier, 1996). Each code is based on a combination of facial expression, gestures, posture, voice tone and volume, and speech rate to capture a gestalt of the affective tone of each moment of behavior. SPAFF consists of 10 mutually exclusive affect codes: contempt, anger, fear/anxiety, sad/withdrawn, whine/complain, neutral, interest/curiosity, humor, joy/excitement, and affection.

Prior to coding, observers were extensively trained to a criterion of 75% agreement and .65 kappa using a frequency/sequence-based comparison and a criterion of 80% agreement using a duration/sequence based comparison (Noldus Observer 5.0). These two reliability methods were employed because state space grid analyses require accuracy in both the onset and duration of events. Weekly recalibration training was conducted to minimize coder drift. Twenty percent of all sessions were coded by one coder and jointly coded by the two coding supervisors. This second file served as the "golden standard" to which each reliability file was compared. Coders were blind to which sessions were used to assess observer agreement. The average coder agreement with the golden standard was 81% and .75 kappa for the frequency-based method and 91% for the duration-based method.

Measures

To induce an emotionally charged interaction, the topics for the conflict discussion were chosen from a modified version of the Issues Checklist (Robin & Weiss, 1980) which lists 18 common issues for parents and children such as cleaning, lying, fighting with siblings, etc. Mothers and daughters each identified whether they had ever argued about each issue and how upset they currently felt about it (on a 5-point scale). The topic for the conflict discussion was chosen from the participants' rankings of the top three most upsetting conflicts.

Girls completed a 26-item inventory of stressful events that had occurred within the past six months, adapted from the Events Checklist (Swearingen & Cohen, 1985). These events included such items as the death of a family member, parents' divorce, moving to a new house, and getting braces. In addition, mothers and daughters each filled out a short questionnaire on pubertal status that included a question about whether the girl had begun menstruating. The count of life events was augmented by 1 for the 14 girls who had begun menstruating. The median number of events reported was 2, and there were two modal values at 0 and 2 events. Previous research indicates that it is the cumulative, rather than sequential, effect of several simultaneous life transitions that has a negative impact on adolescent behavior (e.g., Simmons & Blyth, 1987). Based on this previous research, we divided the total life events count at 3 to create low (less than 3; $n = 34$, $M = 1.0$, $SD = 0.87$, $Mdn = 1$) and high (3 or more; $n = 21$, $M = 3.76$, $SD = 0.94$, $Mdn = 4$, Max = 6) event groups, hereafter identified as the Low and High Stress groups.

State Space Grid Measures

State space grids were constructed with GridWare 1.1 (Lamey, Hollenstein, Lewis, & Granic, 2004) from each observational data file. The two dimensions of the grid corresponded to the mother's expressed emotion on the *x*-axis and the daughter's expressed emotion on the *y*-axis. The 10 possible states (SPAFF codes) for each participant were arranged on each axis in an ordinal sequence from the most negative to the most positive. Thus, the state space grid for this study consisted of 100 cells. Each cell on the grid represents a potential "dyadic state." As shown in Figure 1, a new point was plotted for each change in dyadic (either partner's) behavior. Two flexibility measures are reported here and each represents a primary dimension of flexibility (Hollenstein et al., 2004): the range of dyadic states and the frequency of changes among those states. *Dispersion*, or spread of behavior across cells, is the sum of the squared proportional durations across all cells, adjusted for the total number of cells in the grid matrix, and inverted so that values range from 0 (no dispersion: all behavior in one cell) to 1 (maximum dispersion: behavior equally distributed across the grid). This measure is created by the formula:

$$[(n\Sigma(d_i/D)^2) - 1]/n - 1$$

where D is the total duration, d_i is the duration in cell i, and n is the total number of possible cells in the grid. *Transitions* represents the number of changes or movements between cells on the grid. Slight variations in the duration of each discussion were controlled for by transforming counts to rates per minute. For both measures, higher values denote greater flexibility and these measures were correlated with each other in each discussion (see Table 1).

The state space grid was also divided into theoretically distinct regions based on whether negative emotion was expressed. Our primary region of interest was the L-shaped portion of the grid pertaining to dyadic states in which one or both participants were expressing negative emotions (see Figure 1). We chose this region because we measured simultaneous emotional states and, in the course of conversation, two people are rarely expressing negative emotion simultaneously (except perhaps in the most heated arguments or in atypical populations). One person may express negative emotion while the other listens with interest and then, later, those roles are reversed. In parent-child interactions especially, it is more likely that complementary (i.e., sadness and affection), rather than identical, emotions are expressed. Therefore, we chose to be inclusive rather than limit the measure of negative emotions to only those times when it was mutual. Expressed negative emotion was measured as the total duration[1] of behavior in this region. Because distributions of this variable were skewed, analyses were performed on the log transformed values.

Table 1
Correlations Between Negative Emotion and Flexibility Measures

Measures		1	2a	2b	3
Transitions	Dispersion	.68***	.80***	.66***	.81***
Transitions	Negative emotion	−.02	.54***	.37**	.20
Dispersion	Negative emotion	.20	.56***	.63***	.31*

* $p < .05$. ** $p < .01$. *** $p < .001$.

Results

We tested the manipulation and the first hypothesis by examining the profiles of each measure across discussions for evidence of a quadratic shape. That is, we expected opposite quadratic patterns for Negative Emotion (low-high-low) and Flexibility (high-low-high). Planned quadratic contrasts in separate repeated-measures analysis of variance (ANOVAs) were significant for each measure (see main effects in Table 2). There was more Negative Emotion expressed and smaller values for Transitions and Dispersion in the conflict discussion relative to the two positive discussions. Thus, as expected, the conflict discussion did indeed elicit an increase in expressed negative emotion and a decrease in interpersonal flexibility.

We also hypothesized that stressed dyads would be more negative and less flexible than their unstressed counterparts. The same three repeated-measures ANOVAs were run as before, except that Stress group was included as a between-subjects factor (see Figure 2). First, we tested whether the High Stress group expressed more Negative Emotion or were less flexible overall. Contrary to expectations, the between-subjects main effect of Stress group (collapsing across Discussions) was not significant for Dispersion, $F(1, 53) = 1.39$, *ns*, or Transitions, $F(1, 53) = 2.80$, *ns.* Also contrary to expectations, the High Stress group had lower durations in the Negative Emotion region in every discussion (see Figure 2), but this between group main effect was only marginally significant, $F(1, 53) = 3.58$, $p = .06$. Next, we explored whether there was a quadratic interaction between each repeated-measures factor and Stress group. As shown in Table 2, there were no

[1] It should be noted that the pattern of results was identical when either the frequency or mean duration measures of negative emotion were analyzed rather than the total duration.

Table 2
Means, Standard Deviations, and Repeated-Measures ANOVA Results: Overall Quadratic Contrast and Quadratic Interaction With Stress Group

	Discussion				Main effect		Interaction	
Measure	1	2a	2b	3	Quadratic F	Partial η^2	Quadratic F	Partial η^2
Negative emotion[a]	4.4 (12.7)	16.0 (26.2)	16.5 (37.7)	3.8 (8.8)	27.35***	.34	0.08	.002
Transitions	7.72 (2.41)	5.32 (2.43)	5.21 (2.31)	6.79 (2.39)	38.92***	.42	6.04*	.10
Dispersion	0.41 (0.11)	0.34 (0.17)	0.34 (0.15)	0.37 (0.13)	6.96**	.12	2.19	.04

Note. Degrees of freedom for all analysis of variance (ANOVAs) = 1, 53. Interaction result refers to quadratic interaction between within-subjects factor (Discussion) and between-subjects factor (Stress group).
[a] Duration in Negative emotion region (due to skewed distributions, these variables were log transformed for analyses).
* $p < .05$. ** $p < .01$. *** $p < .001$.

significant quadratic interactions between Stress group and Negative Emotion or Dispersion. Hence, the groups did not differ in their quadratic profiles: changes in the amount of time that Negative Emotion was expressed and in the Dispersion across the state space were similar for both groups (Figure 2). However, there was a significant quadratic interaction between Stress group and Transitions— our other measure of flexibility (Table 2). The Low Stress group showed a distinct quadratic profile for Transitions, as expected, whereas the High Stress group showed a comparatively flat profile. As can be seen in Figure 2, between-group differences were only evident for the positive discussions. In fact, pairwise comparisons with a Bonferroni correction revealed a significant difference in Transitions only in Discussion 1, $F(1, 53) = 8.14$, $p = .006$, $\eta^2 = .13$. Thus, it appears that the High Stress group interacted less flexibly at first, when discussing a fun topic, but was no different from the Low Stress group in subsequent discussions.

To further explore individual differences in the relations between Negative Emotion and Flexibility, we also examined the correlations between these measures within each discussion. As shown in Table 1, the correlations between the Flexibility measures and Negative Emotion were mostly positive, and these correlations were strongest by far, and consistently significant, in the conflict discussion. This indicates that, in terms of individual differences, those dyads who expressed more negative emotion during conflict were also more flexible.

Discussion

The goal of the present study was to examine the relations between negative emotions and dyadic flexibility during pleasant versus conflictual situations at the onset of adolescence. Expressed negative emotion was shown to peak when mothers and daughters discussed conflictual topics. This pattern of results confirmed that our manipulation was successful and that conflict interactions were indeed more negatively valenced. As predicted, flexibility showed the inverse profile across the three discussions. Flexibility was highest in the first (positive) discussion, lowest during the conflict discussion, and returned close to baseline in the third (positive) discussion. This pattern confirmed the hypothesis that an increase in negative emotion would correspond with a decrease in emotional flexibility. Thus, increasing negative emotion by manipulating the context of interpersonal interactions seemed to produce a narrowing of expressive behavior, similar to the narrowing of cognitive activity corresponding with increased negative emotion in laboratory studies (e.g., Isen, 1987; Mathews & MacLeod, 1985). It is likely that similar processes underlie both cognitive and interpersonal flexibility, such as the control of attentional focus and the inhibition of prepotent or impulsive responses. When discussing a fun topic, these dyads may have maintained a wide attentional focus and been less inhibited both in their thinking and in their emotional reactivity. In contrast, during a conflictual discussion, both more focused attention and greater inhibition might be necessary in order to communicate effectively in the presence of negative emotion. Emotional responses may have been more restricted or more tightly regulated, in keeping with these attentional constraints. These parallels between cognitive processes and interpersonal flexibility warrant further investigation.

The differences between stress groups were partly consistent with our hypotheses and partly unexpected. The high stress dyads were less flexible during the first positive discussion, and, indeed, we expected them to show less flexibility at some point, if not consistently. However, this group expressed less negative emotion overall, contrary to expectations. Visual inspection of the pattern of changes across discussions indicates that the high stress dyads also responded less strongly to the manipulation—the profiles of Dispersion and Flexibility were relatively flat in comparison to the distinct U-shaped profiles of the low stress dyads. Thus, these dyads may have adapted to stressful events by suppressing emotional expression and thus reducing flexibility. These differences, especially in the first discussion, may further suggest a resistance to engaging emotionally in this novel social situation. Perhaps these mothers and daughters were attempting to avoid further stress by expressing less negative emotion to each other, and this may have contributed to their initial low flexibility. Indeed, there is some limited evidence that coping with stress reduces flexibility (Carris, Sheeber, & Howe, 1998) and that a common coping strategy during adolescence is withdrawal or avoidance (Compas, Connor-Smith, Saltzman, Thomsen, & Wadsworth, 2001). Alternatively, it may be that those who are less flexible and less emotionally expressive are also prone to experiencing more stress. For example, Butler et al. (2003) found that conscious suppression of emotions increased physiological stress responses and disrupted interpersonal communication. However, the present study cannot distinguish whether stressful events preceded or followed the onset

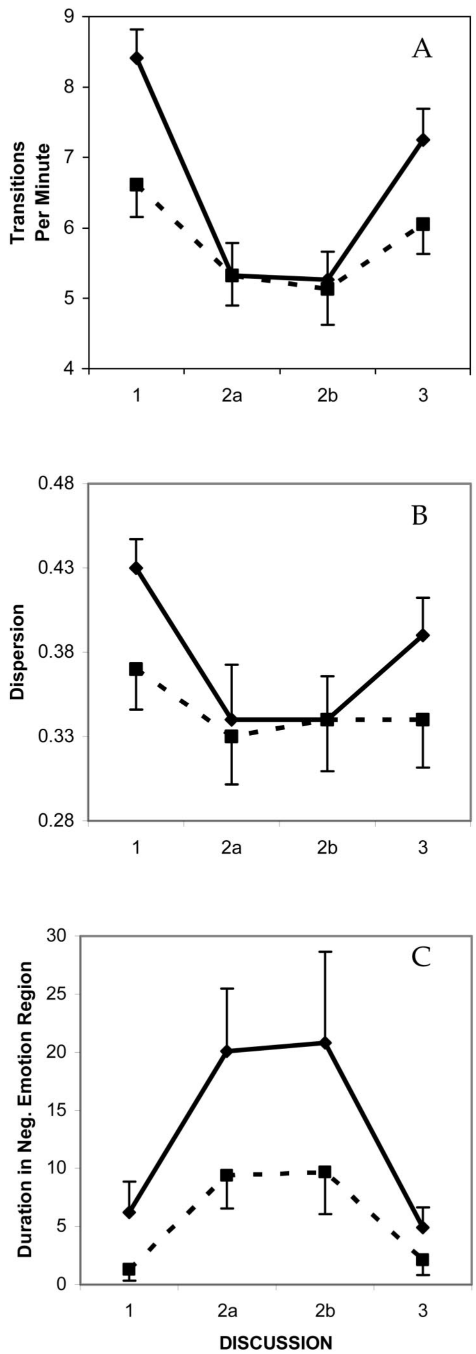

Figure 2. Mean values for the Low and High Stress groups in each of the discussions for each measure: Transitions (Panel A), Dispersion (Panel B), and Negative Emotion (Panel C). The Low Stress group is represented by a solid line and the High Stress group is represented by the dashed line. Note that discussion 2 is broken up into 2a (first 4 minutes) and 2b (last 4 minutes).

of less flexible mother-daughter interactions. These results also suggest a possible link with depression, which is also associated with flattened affect and greater incidence of stressful events (Ge, Lorenz, Conger, Elder, & Simmons, 1994; Graber, 2004).

The correlational analyses were consistent with the results of the stress group comparisons. During the conflict discussion, those dyads who expressed more negative emotion were also more flexible. Those who expressed more negative emotion may have been generally more expressive and, hence, more flexible compared to those with a restricted range of expression. Moreover, considering the correlational and stress group results together, individual differences in emotional expressiveness may be related to a dyad's habitual style of emotion regulation; a tendency to suppress negative emotion (Butler et al., 2003) would account for reduced flexibility as well as reduced negative emotion in both stressed and non-stressed dyads. It is intriguing to note that cross-situational comparisons and individual difference comparisons portray highly distinct aspects of the relation between emotion and interpersonal flexibility.

An alternative explanation for the positive correlations between negative emotion and flexibility may be that our measures of emotion and flexibility were conflated. The expression of more negative emotion might mean that the dyads visited more cells on the state space grid. This increase in the number of dyadic states would produce higher values for Dispersion and possibly Transitions as well. However, if this were the whole story, we would see greater Dispersion values in the conflict discussion compared to either of the positive discussions. Instead, Dispersion was, on average, lowest during the conflict discussion. Hence, the conflation of the measures could not in itself account for the observed correlations.

Taken together, our results indicate a situation-specific decrement in real-time interpersonal flexibility corresponding with an increase in expressed negative emotion, as well as a loss of flexibility associated with stressful life events. Moreover, these results support a nuanced view of negative emotions. Expressing negative emotions may not always be "bad"; rather, interpersonal flexibility may be enhanced in an adaptive way when negative emotions are allowed expression in certain contexts, such as conflict situations.

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