HHS Public Access
Author manuscript
Res Child Adolesc Psychopathol. Author manuscript; available in PMC 2022 May 01.

Published in final edited form as:
Res Child Adolesc Psychopathol. 2021 May ; 49(5): 615–628. doi:10.1007/s10802-020-00763-z.

Mother-Daughter Mutual Arousal Escalation and Emotion Regulation in Adolescence

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Abstract

Adolescence is a period of heightened emotionality, and difficulties with emotion regulation during adolescence are associated with the development of internalizing disorders, especially for girls, who are at elevated risk. Mothers may socialize emotion dysregulation by engaging in frequent interactions with their adolescents that involve mutual increases in arousal. This study tested a model of mother-adolescent mutual arousal escalation in a conflict discussion task in adolescent girls and examined associations between mutual arousal escalation and adolescent emotion regulation. Participants were 97 adolescent girls (M_{age}=12.29[0.81]; 69% White) and their biological mothers. Dyads completed a 5m conflict discussion task; skin conductance level was collected to measure arousal. Adolescent emotion regulation outcomes were assessed using multiple methods, including arousal habituation to a laboratory-based social stressor and self-reported rumination and problem-solving. Multilevel models provided evidence that mother-adolescent dyads vary in the degree to which they mutually escalate or de-escalate arousal during a conflict discussion and in the degree to which mothers “transmit” arousal to adolescents. For dyads high in either mutual arousal escalation or de-escalation, adolescents reported higher rumination. These findings provide evidence for transactional models of emotion socialization and suggest that adolescents in dyads who mutually escalate *or* de-escalate in arousal report more rumination, which may be indicative of a practiced dysregulatory response in stressful contexts (escalation) or a tendency toward cognitive processes that lead to withdrawal from aversive environments (de-escalation).

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Keywords

Emotion socialization; emotion regulation; adolescence; parent-child interaction; electrodermal activity

Emotion regulation is a core transdiagnostic risk factor for psychopathology and is implicated in both internalizing and externalizing disorders (Compas et al., 2017). Examining mutable factors in the development of emotion regulation, such as parental socialization, is critical, as such research may reveal fruitful targets for intervention and treatment. Elucidating the development of emotion regulation in adolescence is of particular importance, as many forms of psychopathology onset during adolescence and pathological patterns emerge and/or solidify during this period (Merikangas et al., 2010; Polanczyk, Salum, Sugaya, Caye, & Rohde, 2015). Epidemiological studies illustrate that depression and anxiety emerge during adolescence, with rates increasing more quickly for girls (Hankin et al., 2015; Merikangas et al., 2010). Some girls may be at greater risk for psychopathology than others, based on temperamental factors (e.g., Tortella-Feliu, Balle, & Sesé Albert, 2010) and/or earlier pubertal maturation compared to peers (Ullsperger & Nikolas, 2017). Early adolescence may be a particularly important developmental window for girls with regard to risk for psychopathology, given the high degree of variability in pubertal status during this period; thus, examining emotion regulation in samples of early adolescent girls enriched for variability in both puberty and temperament is an important area of study. To this end, this study examined emotion regulation outcomes using multiple methods in a transactional model of parent-adolescent emotion socialization. This study leverages a sample of adolescent girls ages 11–13 enriched for variability in risk for depression and anxiety, to test adolescent emotion regulation as predicted by mother-adolescent mutual escalation of physiological arousal during a negative affect-inducing task.

Adolescence as an Important Period for Emotion Regulation Development

The wide array of physical, emotional, and social changes occurring in adolescence make this transition an important period for the development of emotion regulation. In addition to the physical and hormonal changes concomitant with puberty (and their association with risk for psychopathology; Ullsperger & Nikolas, 2017), behavioral and neuroimaging research illustrates that several brain regions undergo remodeling during adolescence that may contribute to increased socioaffective sensitivity and cognitive flexibility in this developmental period (Crone & Dahl, 2012). Adolescents are more sensitive to social context and reward (Blakemore & Mills, 2014; Gardner & Steinberg, 2005) and affective stimuli (Crone & Dahl, 2012). Alongside these increases in social and affective salience, adolescence appears to be a period of increased cognitive *flexibility* and increased cognitive sensitivity to context (Crone & Dahl, 2012).

In concert with these changes, adolescents assume more independence and responsibility for their physical and emotional well-being and make their first forays into adult roles (e.g., employment, romantic relationships). These new roles and changes may be challenging and tax adolescents' developing skills, laying the foundation for novel, emotionally evocative situations and interactions, and subsequently, opportunities to practice regulating one's emotions in social context. The increases in flexibility in executive function occurring in concert with these novel opportunities for emotion responding in affectively salient circumstances may result in adolescence being a key developmental period for emotion regulation more broadly, and for the establishment of both beneficial and problematic patterns of emotion responding in social interactions, specifically. Although the effectiveness of emotion regulation is context-dependent (Weisz, McCabe, & Dennig, 1994), several strategies appear to be more problematic in terms of their association with psychopathology, whereas others appear to be generally protective (Compas et al., 2017; Schäfer, Naumann, Holmes, Tuschen-Caffier, & Samson, 2017). Emotion regulation strategies focused on voluntary engagement and approach, such as problem-solving, are negatively associated with depression and anxiety, whereas involuntary engagement strategies such as rumination are positively associated with internalizing.

Emotion Regulation Development Through Mother-Child Interaction

Parents play a critical role in the development of their children's emotion regulation abilities (Tan, Oppenheimer, Ladouceur, Butterfield, & Silk, 2020). In infancy, emotion is effectively co-regulated within the parent-infant dyad (Kopp, 1982; Sroufe, 1996). This co-regulation, often described as "synchrony", appears to be facilitated by physiological attunement between mother and infant (Feldman, 2012). Throughout the course of early development, mothers gradually transition from serving in this intensive co-regulatory role to teaching, scaffolding, and modeling ever more sophisticated forms of emotion regulation (Perry & Calkins, 2018). As children age into adolescence and develop more independence as well as more sophisticated cognitive abilities, mothers have continued opportunities to promote both positive (e.g., problem-solving) and negative (e.g., rumination) emotion regulation strategies by modeling in their own emotional responding and, most pertinent to this study, through scaffolding and emotion coaching during dyadic interactions with the adolescent (Lougheed, 2020; Morris, Cui, Criss, & Simmons, 2018). Typically, mothers are the primary support agent in the family for coping with negative emotions, even into adolescence (Van Lissa, Keizer, van Lier, Meeus, & Branje, 2018) which may be especially important for adolescent girls, who are more prone to internalizing disorders. These mother-daughter emotion socialization processes may be particularly salient in the early adolescent period, as familial conflict peaks during early adolescence (Laursen, Coy, & Collins, 1998). Further, there is evidence, albeit limited, that similar forms of psychobiological attunement initially apparent in mother-infant co-regulatory processes continue into childhood (e.g., Woody, Feurer, Sosoo, Hastings, & Gibb, 2016) and adolescence (e.g., Amole, Cyranowski, Wright, & Swartz, 2017).

In addition to these broad patterns of mother-adolescent emotion co-regulation and socialization, there may be individual differences in how mothers interact with their adolescents in heightened emotional contexts (e.g., conflict), and in the extent to which mothers are able to successfully scaffold emotion regulation abilities during dyadic interaction. Over time, these individual differences in dyadic emotion dynamics may coalesce into individual differences in adolescent emotion responding (Lougheed, 2020). One particularly problematic pattern may be if the mother exacerbates arousal in the adolescent beyond a responsive, empathetic reaction during conflictual or stressful interactions. Experiencing repeated escalations of arousal during interpersonal conflicts with one's mother may, over time, lead the adolescent to interpret relatively neutral events as negative (i.e., mood-congruent effects, Clark & Waddell, 1983), resulting in increased negative affect and subsequent difficulties with emotion regulation, such as overreacting to neutral events. Alternatively, if one's mother does not respond adequately to the adolescent's arousal (i.e., is not empathetic), the adolescent may exacerbate her behavioral emotional response in an attempt to receive the support desired.

One model for conceptualizing maternal influence on adolescent emotion regulation during dyadic interaction is Butler's temporal interpersonal emotion systems (TIES; 2011, 2015), which integrates the *inter*personal context into the typically *intra*personal components of emotion (behavior, physiology, experience; Butler, 2011). In the context of the mother-child relationship, TIES models aim to elucidate the ways in which mother and child emotion are related to one another, or covary, over time. Research has identified patterns of covariation in behavioral displays of negative affect in mothers and adolescents during stressful mother-adolescent interactions. Mothers and adolescents are temporally reciprocal in their behavioral displays of negative affect (Main, Paxton, & Dale, 2016; Sheeber, Allen, Davis, & Sorensen, 2000), with one study indicating that mothers drive this effect in interactions with mid-adolescents (ages 13–14; Main et al., 2016). Similarly, adolescents whose mothers displayed more aversive behaviors in a positively-valenced interaction task were more likely to reciprocate aversive and dysphoric behaviors in a conflict interaction task, and reported that they used more negative emotion regulation strategies (Yap, Schwartz, Byrne, Simmons, & Allen, 2010). Further, adolescents at high risk for depression and their mothers exhibited more dyadic negative affect escalation in a conflict task compared to low-risk adolescents and their mothers (McMakin et al., 2011), indicating that negative affect escalation may be implicated in psychopathological processes in at-risk dyads and highlighting the need to examine negative affect escalation as a predictor of emotion regulation. However, several limitations of these studies merit noting. These studies did not always examine change over time (i.e., examining negative affect synchrony rather than escalation) and those studies that did examine negative affect escalation did not examine the association of such escalation with adolescent emotion regulation abilities.

In addition to behavioral covariation, there is evidence of covariation in *physiological* emotion response in mother-adolescent dyads. Physiological indices of emotion possess several characteristics beneficial for assessing mother-child covariation in emotion responding. First, many physiological indicators have high temporal resolution, producing measurements on the scale of seconds, allowing researchers to capture sensitive, moment-to-moment measures of emotion response. Second, physiological measures of emotion response may reflect a wide array of interpersonal dynamics operating on very brief timescales, such as facial affect and body language, that may be communicated to an interaction partner before individuals have conscious awareness of their emotional response (e.g., Tooley, Carmel, Chapman, & Grimshaw, 2017). Third, physiological indicators provide a more objective (albeit less specific) measure of emotion response than self-report or observer-coded affect (Kassam & Mendes, 2013). Hence, physiological measures of emotion response are well positioned to capture the temporal interpersonal emotion dynamics between mother and adolescent.

There is ample research on the physiological emotional attunement of mothers and infants/young children and between adult romantic partners (see Palumbo et al., 2017, meta-analysis and Timmons et al., 2015, review). However, there is little research examining physiological covariation between mothers and adolescents, especially in negative affect-inducing contexts. The majority of the limited studies in this area have examined dyadic high frequency heart rate variability (or respiratory sinus arrhythmia [RSA]) as an index of parasympathetic nervous system response in clinical samples. The results of these studies paint a complex and occasionally contradictory picture regarding patterns of physiological covariation during stressful dyadic interaction (Davis, West, Bilms, Morelen, & Suveg, 2018). Several studies support the notion of blunted or dysregulated dyadic physiological response (e.g., lack of covariation, reduced RSA in response to aversiveness, reduced flexibility) in dyads with or at risk for depression (Amole et al., 2017; Crowell et al., 2014). Conversely, one study indicates that maternal expressions of negative affect (anger) may lead to decreased adolescent RSA, which the authors interpreted as indicative of decreased regulatory ability (Cui et al., 2015).

In addition to RSA, skin conductance level (SCL) is a frequently used physiological indicator of emotion. A form of electrodermal activity in which a direct current is applied to the skin under conditions of constant voltage (Boucsein, 2012), SCL reflects tonic levels of sympathetic nervous system (SNS) activity. Under negative affect-inducing conditions, SCL can reasonably be conceptualized as a physiological indicator of negative affect arousal. Although RSA and SCL both provide information regarding psychophysiological arousal, SCL provides superior temporal resolution relative to RSA, thus leaving it better suited for models of dyadic arousal escalation. Further, examining SNS arousal versus more regulatory PNS activation may facilitate a valuable understanding of interpersonal emotion dynamics as they relate to emotion regulation; for example, individuals may continue to experience high levels of SNS arousal in stressful interpersonal contexts, despite recruiting regulatory systems, which may ultimately influence the success or failure of efforts to regulate emotion. To our knowledge, only two studies have examined dyadic patterns of mother-adolescent covariation in SNS arousal as assessed by SCL. In two separate studies conducted in a community sample of adolescent girls and their mothers, Lougheed and colleagues found varying “arousal transmission” effects dependent on the context (Lougheed & Hollenstein, 2018; Lougheed, Koval, & Hollenstein, 2016). Daughters transmitted arousal to mothers during a stressful performance task, but mothers transmitted arousal to daughters during two dyadic interaction tasks designed to elicit negative and positive emotion, respectively. Notably, the latter study did not examine change over time in physiological emotion responding during stressful dyadic interactions, nor did they investigate the relation between dyadic physiological covariation and emotion regulation abilities in the adolescent.

The Current Study

To address these gaps in the literature, the current study examines a transactional model of mutual escalation in arousal, as assessed by SCL, between adolescent girls ages 11–13 and their mothers, and how this arousal escalation is associated with emotion regulation strategy use in the adolescent. Several patterns of mother-adolescent emotion dynamics have been observed in the literature (Lougheed, 2020). First, mothers and children may track together concurrently over time around a *stable level* either with or without consideration of which partner is driving the change (e.g., concurrent or time-lagged synchrony). These synchronous processes, particularly those in which one or both partners “picks up on” the other partner’s emotion, have been posited to reflect empathetic processes (Butler, 2011; Lougheed & Hollenstein, 2018) that may be disrupted in at-risk dyads or dyads with psychopathology (Amole et al., 2017). Alternately, and of particularly interest for this study, mothers and children may track together over time while one or both partners change in mean level of emotion, again with the possibility of examining which partner may be driving the effect (transmission, contagion, escalation, de-escalation with or without time lagged effects; here, mutual escalation of arousal).

This study was conducted in two stages. First, the degree to which mothers and adolescents escalated in arousal over time – both individually and together – and the extent to which mothers and daughters drove changes in the other partner’s arousal (cross-lagged effects) was examined via longitudinal growth curve modeling in a multilevel model for distinguishable dyads, an intensive longitudinal method examining transactional associations at the micro timescale. Second, mutual arousal escalation and arousal transmission effects were used to predict adolescent emotion regulation as assessed in two ways: 1) global self-report of emotion regulation, and 2) physiological arousal habituation during a stressful lab task. The study was conducted in a sample of adolescent girls recruited to ensure variability in emotional reactivity based on oversampling of shy and fearful temperament.

Hypotheses

We hypothesized that, on average, mothers and adolescents would increase in arousal from the beginning to the end of the conflict discussion task (hypothesis 1.1). Further, consistent with previous research (Lougheed & Hollenstein, 2018), we hypothesized that on average, mother’s arousal would predict change in adolescent’s arousal (above and beyond the adolescent’s arousal at the previous time point; hypothesis 1.2), but adolescent’s arousal would not predict change in mother’s arousal (above and beyond the mother’s arousal at the previous time point; hypothesis 1.3). In addition to these fixed effects, we predicted there would be significant individual differences in the extent to which dyads mutually escalated (i.e., significant random effects of time for parents and adolescents; hypothesis 1.4). Further, we predicted that dyadic mutual arousal escalation would be positively associated with self-reported adolescent rumination (hypothesis 2.1), negatively associated with self-reported adolescent problem-solving (hypothesis 2.2), and associated with slower habituation to stressful performance (hypothesis 2.3). Finally, we hypothesized cross-lagged effects of mother arousal on adolescent arousal would predict adolescent emotion regulation. Overall, maternal cross-lagged effects, theorized to reflect broadly empathetic processes, were expected to be associated with more adolescent problem-solving (hypothesis 3.1).

Method

Participants

Participants were drawn from a longitudinal study examining emotional, neural, and social factors in the development of psychopathology in adolescent girls. All study procedures were approved by the Institutional Review Board at the University of Pittsburgh. One hundred and twenty-nine adolescent girls were recruited such that two-thirds of the sample was high risk and one-third low risk for emotional reactivity, as indicated by the Fear and Shyness subscales of the Early Adolescent Temperament Scale – Revised (EATQ-R). High-risk status was defined as scoring 0.75 SD above the mean on either the Fear or Shyness subscale (administered during an online pre-screen). Exclusion criteria included: current/past DSM-5 diagnosis of an anxiety disorder (with the exception of specific phobia) or major depressive disorder; IQ <70; lifetime DSM-5 diagnosis of psychotic disorder or autism spectrum disorder; presence of head injury or neurological anomalies; psychoactive or endocrine-disrupting medications (except stimulants); acute suicidal risk or risk of harming self or others. Informed consent and assent were obtained from parents and adolescents, respectively, by a trained post-baccalaureate research assistant prior to the start of procedures at the first lab visit.

Missing Data

Seven participants did not complete the relevant lab visit, and eight had a non-biological mother as participating parent (e.g. father, custodial grandparent). Seventeen dyads were excluded due to missing task data (three dyads) or exhibited bad SCL signal (11 dyads) or signal loss affecting more than 120s in either adolescent or parent (four dyads), resulting in a total of 97 dyads included in analyses (*M*age=12.29[*SD*=0.81]; 69% White). For physiological habituation analyses, three participants were lost due to bad SCL signal on the speech task. There were no significant differences in study variables between participants included in analyses and those who were not.

Procedure

Participants completed a series of online questionnaires and a laboratory visit during which they completed a number of behavioral tasks, including a stressful performance task and several dyadic interaction tasks that the participant completed with a participating parent. (As there were only a small number of participating non-biological mothers, only dyads with participating biological mothers were included in analyses; information on the final sample and missing data is included below.) SCL was measured throughout the visit, as described below.

Laboratory Tasks

Speech Task—Participants had two minutes to prepare a two-minute speech arguing why they should be selected for a fictional reality TV show (Allen et al., 2020). The speech was performed in front of two confederate judges who were instructed to respond in prescribed ways; one judge alternated between neutral expression and smiling, whereas a second, potentially critical judge maintained a neutral expression, shuffled feet, and looked toward and away from the participant at designated intervals. If the participant stopped speaking for over 30 seconds, she was prompted by research staff to continue, and if participants exhibited considerable distress (e.g., crying) at the prospect of completing the task, the task was skipped.

Conflict Discussion Task—Participants and their mothers completed a modified version of the Issues Checklist (Prinz, Foster, Kent, & O'Leary, 1979) to identify areas of frequent disagreement. Dyads were instructed to discuss the problem and attempt to identify solutions for five minutes. A manipulation check was conducted in order to ensure the task elicited primarily negative emotion. Change scores from resting baseline to post-task on ratings of happiness, sadness, and anxiety were calculated to determine whether negative affect increased as a result of the task. Results indicated that both mothers and daughters exhibited decreased happiness and increased sadness following the task; details can be found in Online Resource 1.

Physiological Data Collection

Electrodermal activity (EDA) was acquired from both adolescent and mother using MindWare Mobile wireless systems and recorded with MindWare BioLab v3.1.2 software using a 500 Hz sampling rate. EDA was recorded using Ag/AgCl electrodes, which were attached to the thenar and hypothenar eminences of participants' right palms. EDA signal was inspected, filtered, and analyzed by MindWare EDA Analysis v3.1.3. A rolling filter with a 500-block size smoothed the signal and prevented identification of false skin conductance responses resulting from noise. SCL was used as the tonic component of EDA and calculated through optimized Continuous Decomposition Analysis. SCL was calculated for each 10-second epoch of the tasks, resulting in 30 and 12 total measurements during conflict discussion and the speech task, respectively. To reduce non-theoretically meaningful between-person differences resulting from dermal thickness, data were standardized within person using percent of maximum possible (POMP) scoring (Cohen, Cohen, Aiken, & West, 1999).

Emotion Regulation Outcomes

Rumination—Participants reported their global tendency to ruminate using the 10-item rumination subscale (α = .89) of the Children's Response Style Scale (CRSS; Ziegert & Kistner, 2002). Participants reported how often they respond to sadness with rumination ("I replay in my head what happened.") on a scale of *0 = Never* to *10 = Always*.

Problem-solving—Adolescents reported their global tendency to engage in problem-solving on the Responses to Stress Questionnaire, Social Stress Version (RSQ; (Connor-Smith, Compas, Wadsworth, Thomsen, & Saltzman, 2000) on three items scored from *1 = Not at all* to *4 = A lot.* To operationalize problem-solving, the three items from the problem-solving subscale were summed ("I tried to think of different ways to change the problem or fix the situation.", "I asked other people for help or for ideas about how to make the problem better.", "I did something to try to fix the problem or take action to change things."; α = .55)

Physiological Regulation—Physiological response to the two-minute speech task served as a third measure of emotion regulation. Physiological regulation, or habituation, during stress was operationalized as slope of SCL over the two-minute task.

Covariates

Age—Adolescent age was calculated to the day and group-mean centered.

Pubertal Status—Pubertal status was assessed using the Pubertal Development Scale total score (PDS; Petersen, Crockett, Richards, & Boxer, 1988).

Race—As SCL varies based on race (Janes, Hesselbrock, & Stern, 1978; Kredlow et al., 2017), adolescent and mother race (0 *= White; 1 = non-White*) were included.

Socioeconomic Status—Socioeconomic status was included as a group-mean centered continuous variable of annual gross income in dollars from *0 = 0 – 10,000* to *10 = 100,000+.*

Analytic Approach

Analyses occurred in two stages: 1) a test of cross-lagged arousal escalation, and 2) a test of the effects of cross-lagged arousal escalation on adolescent emotion regulation outcomes.

Stage 1: Mutual Escalation of Arousal

Mutual escalation of arousal was tested using longitudinal growth curve modeling in a multilevel model for distinguishable dyads (Bolger & Laurenceau, 2013) in R using the nlme package (Pinheiro, Bates, DebRoy, Sarkar, & R Core Team, 2018). Consecutive model testing was conducted to evaluate model fit, using Aikaike's information criterion (AIC), the Bayesian information criterion (BIC), and −2 log likelihood (−2LL), where smaller values indicate better fit. Where possible, likelihood ratio tests (LRT) were used to test the significance of improvements in model fit. In order to test arousal escalation, time was included as a predictor of arousal and individuals were allowed to vary in both their intercept and slope of time. A 20s lag and cross-lag was used in all models. The primary parameters of interest for negative affect escalation include mother and daughter random slopes, which can be interpreted as the degree to which mothers and daughters individually escalated in their arousal per unit time, as well as the interaction between mother and daughter random time slopes, which can be interpreted as the degree to which mother and daughter dyads increased or decreased in arousal together per unit time (mutual arousal escalation). Multilevel models were specified as follows:

$$\text{Level 1: } \text{Arousal}_{ti} = \beta_{0Mi} + \beta_{0Di} + \beta_{1Mti}(\text{time}_{ti}) + \beta_{1Dti}(\text{time}_{ti}) + \beta_{2Mi}(\text{Arousal}_{Mt-Xi}) + \beta_{2Di}(\text{Arousal}_{Dt-Xi}) + \beta_{3Mi}(\text{Arousal}_{Dt-Xi}) + \beta_{3Di}(\text{Arousal}_{Mt-Xi}) + \varepsilon_{ti}$$

$$\begin{aligned} \text{Level 2: } \beta_{0Mi} &= \gamma_{00M} + \upsilon_{0Mi} & \beta_{0Di} &= \gamma_{00D} + \upsilon_{0Di} \\ \beta_{1Mi} &= \gamma_{10M} + \upsilon_{1Mi} & \beta_{1Di} &= \gamma_{10D} + \upsilon_{1Di} \\ \beta_{2Mi} &= \gamma_{20M} + \upsilon_{2Mi} & \beta_{2Di} &= \gamma_{20D} + \upsilon_{2Di} \\ \beta_{3Mi} &= \gamma_{30M} + \upsilon_{3Mi} & \beta_{3Di} &= \gamma_{30D} + \upsilon_{3Di} \end{aligned}$$

Parameters:

$\beta_{0Mi,}\ \beta_{0Di}$ = Random intercept for mothers, daughters

$\beta_{1Mi,}\ \beta_{1Di}$ = Random slope of time for mothers, daughters

$\beta_{2Mi,}\ \beta_{2Di}$ = Random autoregressive/lagged effect for mothers, daughters

β_{3Mi}, β_{3Di} = Random cross-lagged effect for mothers, daughters (arousal transmission)

$\gamma_{00M}, \gamma_{00D}$ = Fixed arousal intercept for mothers, daughters

$\gamma_{10M}, \gamma_{10D}$ = Fixed effect of time for mothers, daughters

$\gamma_{20M}, \gamma_{20D}$ = Fixed slope of autoregressive effect for mothers, daughters

$\gamma_{30M}, \gamma_{30D}$ = Fixed slope of lagged effect for mothers, daughters

$\upsilon_{1Mi}, \upsilon_{1Di}$ = Between-person variance

ε_{ti} = Within-person residuals

Stage 2: Adolescent Emotion Regulation as Predicted by Degree of Mutual Escalation

The effects of mutual arousal escalation on emotion regulation outcomes (rumination, problem-solving, physiological habituation) were assessed using multiple regression. Individual slopes of time for mother and daughter and individual cross-lagged effects were generated by saving the best linear unbiased predictors from the final multilevel model. Mother slope, daughter slope, and their interaction (i.e., mutual escalation) were entered into a multiple regression model along with the random maternal cross-lagged effect and any significant covariates to predict the five emotion regulation outcomes described above. Separate tests were conducted for each outcome, resulting in a total of three hypothesis tests. The familywise error rate for three tests is $p = .017$; as this method of correcting for the rate of false positives is highly conservative, findings that meet the standard of $p < .017$ cutoff will be considered robust, while findings in the range of $p < .05$–.017 will be interpreted with caution.

Results

Preliminary Analyses

Sample descriptives and correlations between study variables are presented in Table 1. Online Resource 2 contains descriptive figures of adolescent/mother slope and dyadic escalation.

Physiological Regulation: Adolescent Arousal Slope—Adolescent physiological regulation during the speech task was generated by extracting individual linear slopes from multilevel models of adolescent SCL (lme4; Bates, Maechler, Bolker, & Walker, 2015). On average, adolescents decreased in arousal throughout the task, reflecting habituation to the stress of the task. Individual slope coefficients were extracted.

Dyadic Model Building

Means-Only Model—Model fit statistics are depicted in Table 2. First, a means-only model was run specifying separate random intercepts for mothers and adolescents, to confirm that there were significant individual differences in mean levels of SCL over time and to generate intraclass correlation coefficients (ICC; ICC_{adol}=.15; ICC_{mom}=.14). ICCs indicated that 15% and 14% of the variance in SCL was due to between-person factors and

85% and 86% of the variance was due to within-person factors for adolescents and mothers respectively. ICCs were consistent with the POMP scoring approach implemented to maximize within-person differences and minimize theoretically non-meaningful between-person differences.

Growth Models—A series of growth models were consecutively tested to evaluate the hypothesized mutual escalation model. First, an unconditional growth model was run with time as a fixed-effect predictor. A likelihood ratio test indicated significant model improvement (p<.001; Table 2). Contrary to hypotheses, on average SCL decreased slightly from the beginning to the end of the task for mothers (t=−9.60, p<.001; hypothesis 1.1). Adolescent slope was not significant as a fixed-effect predictor, indicating adolescents did not increase or decrease in arousal throughout the task on average, contrary to hypotheses (t=0.29, p=.77; hypothesis 1.1). Second, a random effect of time was added, resulting in significant model improvement (p<.001), indicating that there were significant individual differences in slope of arousal across the task (hypothesis 1.4). However, mother-adolescent slope covariance was zero, indicating that mothers and adolescents did not consistently covary in arousal throughout the task.

Lagged Models—Finally, a series of models were run to evaluate the hypothesized lagged and cross-lagged effects of arousal. First, 20s lagged arousal was added. AIC, BIC, and −2LL all decreased, indicating improved fit. Both mother and adolescent 20s lagged arousal were significant positive predictors of concurrent SCL (Table 3). Notably, when the 20s lag was added to the model, adolescent slope became significant, indicating a significant increase in arousal on average across the task for adolescents adjusting for autoregressive effects (t=1.97, p=.048). As no random effects of lagged arousal were hypothesized, those models were not tested.

Second, a model was run incorporating 20s cross-lagged arousal for both mother and adolescent. The model improved marginally, as indicated by minor decreases in AIC and −2LL, although BIC increased slightly. LRT indicated marginal model improvement; however, as effects of random cross-lagged arousal were hypothesized, the fixed effect was retained. Albeit only marginally significant, consistent with hypotheses, mother arousal at $time_{t-2}$ positively predicted adolescent arousal at $time_t$ (t=1.90, p=.057; Hypothesis 1.2), but adolescent arousal at $time_{t-2}$ did not significantly predict mother arousal at $time_t$ (t=−1.25, p=.21; Hypothesis 1.3). Mother and adolescent cross-lags were also tested as random effects. The model with a random effect of adolescent cross-lag (adolescent arousal at $time_{t-2}$ predicting mother arousal at $time_t$) did not converge. However, the model significantly improved via likelihood ratio test (p<.001) when a random effect of mother cross-lag (mother arousal predicting adolescent arousal) was added. This model was retained as the final dyadic model. Random effects coefficients were generated for mother slope, adolescent slope, and mother-to-adolescent arousal transmission and exported for use in regression analyses of emotion regulation outcomes. Covariates were tested in final dyadic multilevel models; no covariates were significant.

Emotion Regulation Analyses

The effects of mutual arousal escalation on rumination, problem-solving, and physiological regulation were tested via multiple linear regression in R. First, covariates were tested for significance and dropped if non-significant. Second, individual mother arousal slope, adolescent arousal slope, their interaction, and mother-to-adolescent cross-lag coefficients exported from dyadic multilevel models were entered, along with any significant covariates.

Rumination—Adolescent self-reported rumination was significantly predicted by age: older adolescents reported higher levels of rumination (β=.255, p=.035). However, age was no longer significant when hypothesized predictors were entered into the model (Table 4). Mother and adolescent arousal slope interacted to predict rumination (Figure 1). Simple slopes analyses and regions of significance tests indicated that when mother arousal slopes were greater than 0.80 *SD* above the mean, adolescents with positive arousal slopes reported higher levels of rumination (i.e., mutual arousal escalation was associated with higher rumination; hypothesis 2.1). Additionally, when mother arousal slopes were more than 0.78 *SD below* the mean, adolescents with negative arousal slopes reported higher levels of rumination (i.e., mutual arousal *de-escalation*).

Problem-Solving—Problem-solving was not significantly associated with covariates or with mother arousal slope, adolescent arousal slope, mutual arousal escalation (Table 4; hypothesis 2.2), or mother-to-adolescent arousal transmission (hypothesis 3.1).

Physiological Regulation—Adolescent physiological regulation, operationalized as slope of arousal during the speech task, was not significantly associated with any covariates (Table 4). On average, adolescents decreased in arousal throughout the speech task (as expected), reflecting habituation to the stress of the task. Adolescent physiological regulation during the speech task was unrelated to parent or adolescent arousal slope during the conflict discussion, mutual arousal escalation, or mother-to-adolescent arousal transmission (hypothesis 2.3).

Discussion

To our knowledge, this was the first investigation of dyadic physiological arousal escalation in parent-adolescent dyads. The findings of this investigation show that physiological responses to stressful interpersonal interactions vary widely at both the individual and dyadic levels. During the conflict discussion interaction task, some individuals increased in arousal, some decreased, and dyads varied significantly in the extent to which they moved together or independently (i.e., mutual escalation) throughout the interaction. These dyadic differences were wide ranging, as indicated by the lack of parent-adolescent random slope correlation; that is, there did not appear to be an overarching trend with regard to whether parents and adolescents track upwards or downwards together, or track together at all, for that matter. These findings emphasize the importance of considering variability and dynamic change over time when examining dyadic emotion socialization processes (Butler, 2015). Although there were few average effects of individual change in arousal over time or dyadic covariation in arousal, there were random effects, and as will be discussed below, these individual and dyadic differences were associated with adolescents' independent emotion regulation.

In addition to individual and dyadic variation in arousal change over time, we also found preliminary evidence that mothers may "transmit" arousal to adolescents throughout the task on average, such that increases or decreases in mothers' arousal were followed by corresponding increases or decreases in adolescent arousal, consistent with hypotheses and with previous literature (Lougheed & Hollenstein, 2018), though only marginally statistically significant. Dyads also varied in the degree to which adolescents were influenced by their mothers' arousal, a novel finding. A previous study found that mother-daughter dyads did not differ in mother-to-adolescent arousal transmission, either in general or dependent on self-reported relationship closeness or experimentally manipulated physical closeness (Lougheed & Hollenstein, 2018); however, this study was conducted in a community sample of older adolescents (14–17). It may be that there is more variability in these processes earlier in adolescence and that patterns solidify by mid- or late adolescence. Some research on the transmission of behaviorally coded negative affect indicates that mothers typically "drive" negative interactions in early adolescence, whereas the pattern reverses in older adolescence, with adolescents driving the effect (Main et al., 2016). It is also possible the additional variability observed here reflects the increased emotional reactivity in the high-risk adolescents in the sample. Conversely, adolescent arousal did not systematically predict mothers' future arousal on average, and there were not meaningful dyadic differences in the extent to which adolescents transmit arousal to mothers. Although running counter to substantial research documenting robust child effects on parent emotions and behavior, these findings are broadly consistent with past dyadic research, although one study found evidence of variability in adolescent-to-mother arousal transmission dependent on experimental manipulation of physical closeness (Lougheed & Hollenstein, 2018).

There are several possible explanations for these findings. As theorized above, greater adolescent responsivity to mother arousal may be indicative of empathetic relationships between parent and child, in line with developmental theories of psychobiological attunement (Feldman, 2006). Previous research in this area with mother-adolescent dyads found that adolescents transmitted arousal to mothers when giving a stressful speech (Lougheed et al., 2016) but mothers transmitted arousal to adolescents in the context of both positive and negative interpersonal interactions (Lougheed & Hollenstein, 2018). It may be that when an adolescent is engaged in a stressful activity in the presence of their mother, the mother is more attuned to their child's arousal in an effort to provide social support. However, in stressful interpersonal discussions, such as in the conflict discussion task here, mothers may serve an emotion-coaching or emotion-scaffolding role, communicating to adolescents socially appropriate up- and/or down-regulation of arousal (Morris et al., 2018). Alternately, parents may be better at regulating their emotions in the moment, and/or may be more habituated to adolescent displays of negative affect or arousal, which become more frequent during this developmental stage (Casey et al., 2010). Adolescents, on the other hand, may be broadly more reactive to social input, consistent with developmental theories of adolescence (Crone & Dahl, 2012), or less used to displays of arousal or negative affect by their mothers. Hence, they may be more sensitive to arousal changes in their mothers and more likely to react in kind.

Further, the nature of adolescents' interactions with their mothers was associated with adolescents' own self-reported emotion regulation abilities. Mother-adolescent mutual escalation of arousal was associated with higher adolescent rumination, supporting hypotheses. As theorized, these higher levels of adolescent rumination may result from adolescents frequently "practicing" a dysregulatory style in stressful interactions with their mothers that ultimately translates to the adolescent attempting similar approaches when regulating negative emotion independently. It may be that this association represents a global emotion regulatory "style" in which both thoughts and arousal spiral out of control; mutual escalation in arousal may reflect an interpersonal and physiological manifestation of an inability to inhibit these cognitive or physiological responses in the context of stressful interpersonal situations. In addition, individuals who engage in high levels of rumination also tend to engage in more co-rumination (Rose, 2002), which theoretically could be linked to mutual escalation. It is important to note, however, that given that this was a sample enriched for risk for emotional reactivity, this finding may be related to shared genetic risk for internalizing disorders, which may also account for the higher levels of adolescent rumination observed (M. N. Moore et al., 2013).

Conversely, and rather surprisingly, high levels of mutual *de-escalation* of arousal were also associated with higher adolescent rumination. One possibility is that these mothers and adolescents experienced the highest anticipatory arousal prior to the task, which may be evidence of higher emotional reactivity, and it is this increased emotional reactivity that ultimately accounts for adolescent reports of greater rumination. Alternately, the decrease in arousal observed may be evidence of the use of cognitive processes that promote withdrawal from stressful or distressing situations, such as disengaging from the conflict task to avoid uncomfortable interactions or emotions. Rumination has been theorized to function similarly (Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008). However, rumination has also been associated with *higher* levels of physiological arousal, when used to suppress thoughts and emotion (e.g., Hofmann, Heering, Sawyer, & Asnaani, 2009). Alternately, not all who ruminate go on to develop internalizing disorders; perhaps the mothers in the de-escalation group are aware of their child's rumination and implement strategies in stressful dyadic contexts to reduce their own and their child's arousal, which may function as a protective factor. Additional research is needed to test these possibilities.

Clinical Implications

Although these findings are preliminary and require replication, there are potential clinical implications that may serve as inspiration for future research. For example, the association between dyadic patterns of arousal and adolescent rumination suggest that there are family system-level processes that may increase adolescent risk for internalizing disorders, which could be targeted in intervention. Notably, the divergent arousal patterns seen here may suggest that identifying clinical subgroups is necessary in order to personalize interventions for intervention to the needs of a given family. For example, adolescents who engage in mutual escalation of arousal with parents may require intervention at the behavioral level to interrupt and intervene in habitual interpersonal behaviors that lead to dysregulation. By contrast, those who de-escalate in arousal may require intervention focused on techniques to substitute for ruminative styles that may be avoidance-related (e.g., relaxation, mindfulness).

These implications should be considered in the context of the current sample as well; it is possible that different patterns may emerge in clinical populations, such as blunted trajectories of arousal in dyads in which one or both partners are depressed (Bylsma, Morris, & Rottenberg, 2008).

Limitations

Several limitations of this study are worth noting. The sample is limited to adolescent girls and enriched for risk for emotional reactivity, which limits generalizability. Similarly, only biological mother-adolescent dyads were included in this investigation, because dyadic patterns between other caregivers and adolescents differed from those observed between mothers and daughters. This may indicate differing interpersonal patterns with fathers and other caregivers that may influence adolescent emotion regulation in different ways than those presented here. In other words, it may be something unique about mother-adolescent relationships that is producing these results. Unfortunately, the small number of caregivers in this sample that were not biological mothers (n=8) preclude any conclusions about systematic differences in father-daughter dyads or dyads with other caregivers. In a similar vein, although the sample is representative of the surrounding area in terms of race and SES, it is a predominantly White sample and findings may not generalize to more diverse communities. Finally, the use of arousal as the primary indicator may also be limiting inasmuch as SNS arousal is valence-independent; it is unclear that this physiological marker is specifically picking up on negative affect or dysregulation, although manipulation checks indicated the task increased negative affect.

Future directions

As this study was one of the first to test a model of arousal escalation and transmission in mothers and adolescents, and the first to extend those dyadic patterns to adolescent independent emotion regulation, these results should be considered preliminary; replication will be necessary to confirm the robustness of these effects. An important next step will be evaluating concurrent measures of behaviorally expressed emotion to determine whether the escalation in arousal examined here tracks with emotional response in the moment. It would also be worth evaluating whether behaviorally-coded measures of negative escalation, similar to those used in previous studies of negative affect escalation (e.g., McMakin et al., 2011), track with these physiological measures. Additionally, studies examining the effects of these dyadic patterns on the mother's independent emotion regulation are warranted, given established effects of child behavior on parent emotions/behavior (e.g., Moore, Whaley, & Sigman, 2004). In a similar vein, it may be that shared genetic influences between mothers and daughters are driving the effects observed here; future studies leveraging genetically informed designs would be valuable contributions to this area of research. Finally, research examining individual and/or dyadic differences such as behavioral avoidance or withdrawal that may result in these dyadic patterns of arousal over time may aid in identifying which factors contribute to these interactional styles and elucidate potential mechanisms of effect.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

References

Allen KB, Woody ML, Rosen D, Price RB, Amole MC, & Silk JS (2020). Validating a mobile eye tracking measure of integrated attention bias and interpretation bias in youth. Cognitive Therapy and Research, 44(3), 668–677. 10.1007/s10608-019-10071-6 [PubMed: 33518843]

Amole MC, Cyranowski JM, Wright AGC, & Swartz HA (2017). Depression impacts the physiological responsiveness of mother–daughter dyads during social interaction. Depression and Anxiety, 34, 118–126. [PubMed: 28060443]

Bates D, Maechler M, Bolker B, & Walker S (2015). Fitting linear mixed-effects models using lme4. Journal of Statistical Software, 67(1), 1–48. 10.18637/jss.v067.i01

Blakemore S-J, & Mills KL (2014). Is Adolescence a sensitive period for sociocultural processing? Annual Review of Psychology, 65, 187–207. 10.1146/annurev-psych-010213-115202

Bolger N, & Laurenceau J-P (2013). Design and analysis of intensive longitudinal studies of distinguishable dyads. In Intensive Longitudinal Methods: An Introduction to Diary and Experience Sampling Research (pp. 143–176). New York, NY: The Guilford Press.

Boucsein W (2012). Electrodermal Activity (Second Edi). New York, NY: Springer.

Butler EA (2011). Temporal interpersonal emotion systems: The “TIES” that form relationships. Personality and Social Psychology Review, 15(4), 367–393. 10.1177/1088868311411164 [PubMed: 21693670]

Butler EA (2015). Interpersonal affect dynamics: It takes two (and time) to tango. Emotion Review, 7(4), 336–341. 10.1177/1754073915590622

Bylsma LM, Morris BH, & Rottenberg J (2008). A meta-analysis of emotional reactivity in major depressive disorder. Clinical Psychology Review, 28(4), 676–691. [PubMed: 18006196]

Casey BJ, Jones RM, Levita L, Libby V, Pattwell SS, Ruberry EJ, … Somerville LH (2010). The storm and stress of adolescence: Insights from human imaging and mouse genetics. Developmental Psychobiology, 52(3), 225–235. 10.1002/dev.20447 [PubMed: 20222060]

Clark MS, & Waddell BA (1983). Effects of moods on thoughts about helping, attraction and information acquisition. Social Psychology Quarterly, 46(1), 31–35.

Cohen P, Cohen J, Aiken LS, & West SG (1999). The problem of units and the circumstance for POMP. Multivariate Behavioral Research, 34(3), 315–346. 10.1207/S15327906MBR3403

Compas BE, Jaser SS, Bettis AH, Watson KH, Gruhn MA, Dunbar JP, … Thigpen JC (2017). Coping, emotion regulation, and psychopathology in childhood and adolescence: A meta-analysis and narrative review. Psychological Bulletin, 143(9), 939–991. 10.1037/bul0000110 [PubMed: 28616996]

Connor-Smith JK, Compas BE, Wadsworth ME, Thomsen AH, & Saltzman H (2000). Responses to stress in adolescence : Measurement of coping and involuntary stress responses, 68(6), 976–992. 10.1037//0022-006X.68.6.976

Crone EA, & Dahl RE (2012). Understanding adolescence as a period of social-affective engagement and goal flexibility. Nature Reviews Neuroscience, 13(9), 636–650. 10.1038/nrn3313 [PubMed: 22903221]

Crowell SE, Baucom BR, Yaptangco M, Bride D, Hsiao R, Mccauley E, & Beauchaine TP (2014). Emotion dysregulation and dyadic conflict in depressed and typical adolescents: Evaluating concordance across psychophysiological and observational measures. Biological Psychology, 98, 50–58. https://doi.org/doi:10.1016/j.biopsycho.2014.02.009 [PubMed: 24607894]

Cui L, Morris AS, Harrist AW, Larzelere RE, Michael M, Cui L, … Criss MM (2015). Dynamic changes in parent affect and adolescent cardiac vagal regulation: A real-time analysis. Journal of Family Psychology, 29(2), 180–190. [PubMed: 25730403]

Davis M, West K, Bilms J, Morelen D, & Suveg C (2018). A systematic review of parent-child synchrony: It is more than skin deep. Developmental Psychobiology, (April), 1–18. 10.1002/dev.21743

Feldman R (2006). From biological rhythms to social rhythms: Physiological precursors of mother-infant synchrony. Developmental Psychology, 42(1), 175–188. 10.1037/0012-1649.42.1.175 [PubMed: 16420127]

Gardner M, & Steinberg L (2005). Peer influence on risk taking, risk preference, and risky decision making in adolescence and adulthood: An experimental study. Developmental Psychology, 41(4), 625–635. 10.1037/a0026993 [PubMed: 16060809]

Hankin BL, Young JF, Abela JRZ, Smolen A, Jenness JL, Gulley LD, … Oppenheimer CW (2015). Depression from childhood into late adolescence: Influence of gender, development, genetic susceptibility, and peer stress. Journal of Abnormal Psychology, 124(4), 803–816. 10.1037/abn0000089 [PubMed: 26595469]

Hofmann SG, Heering S, Sawyer AT, & Asnaani A (2009). How to handle anxiety: The effects of reappraisal, acceptance, and suppression strategies on anxious arousal. Behaviour Research and Therapy, 47(5), 389–394. 10.1016/j.brat.2009.02.010 [PubMed: 19281966]

Janes CL, Hesselbrock V, & Stern JA (1978). Parental psychopathology, age, and race as related to electrodermal activity of children. Psychophysiology, 15(1), 24–34. 10.1111/j.1469-8986.1978.tb01329.x [PubMed: 625520]

Kassam KS, & Mendes WB (2013). The effects of measuring emotion: Physiological reactions to emotional situations depend on whether someone is asking. PLoS ONE, 8(6), 6–13. 10.1371/journal.pone.0064959

Kopp CB (1982). Antecedents of self-regulation: A developmental perspective. Developmental Psychology, 18(2), 199–214. 10.1037/0012-1649.18.2.199

Kredlow MA, Pineles SL, Inslicht SS, Marin MF, Milad MR, Otto MW, & Orr SP (2017). Assessment of skin conductance in African American and Non–African American participants in studies of conditioned fear. Psychophysiology, 54(11), 1741–1754. 10.1111/psyp.12909 [PubMed: 28675471]

Laursen B, Coy KC, & Collins WA (1998). Reconsidering changes in parent-child conflict across adolescence: A meta-analysis. Child Development, 69(3), 817–832. 10.1111/j.1467-8624.1998.00817.x [PubMed: 9680687]

Lougheed JP (2020). Parent – adolescent dyads as temporal interpersonal emotion systems. Journal of Research on Adolescence, 30(1), 26–40. 10.1111/jora.12526 [PubMed: 31424138]

Lougheed JP, & Hollenstein T (2018). Arousal transmission and attenuation in mother–daughter dyads during adolescence. Social Development, 27(1), 19–33. 10.1111/sode.12250

Lougheed JP, Koval P, & Hollenstein T (2016). Sharing the burden: The interpersonal regulation of emotional arousal in mother − daughter dyads. Emotion, 16(1), 83–93. 10.1037/emo0000105 [PubMed: 26322569]

Main A, Paxton A, & Dale R (2016). An exploratory analysis of emotion dynamics between mothers and adolescents during conflict discussions. Emotion, 16(6), 913–928. 10.1037/emo0000180 [PubMed: 27148849]

McMakin DL, Burkhouse KL, Olino TM, Siegle GJ, Dahl RE, & Silk JS (2011). Affective functioning among early adolescents at high and low familial risk for depression and their mothers: A focus on individual and transactional processes across contexts. Journal of Abnormal Child Psychology, 39(8), 1–22. 10.1007/s10802-011-9540-4.Affective [PubMed: 20644990]

Merikangas K, Jian-ping H, Burstein M, Swanson S, Avenevoli S, Lihong C, … Swendsen J (2010). Lifetime prevalence of mental disorders in US adolescents: Results from the National Comorbidity Study-Adolescent Supplement. Journal of the American Academy Children Adolescent Psychiatry, 49(10), 980–989. 10.1016/j.jaac.2010.05.017.Lifetime

Moore MN, Salk RH, van Hulle CA, Abramson LY, Hyde JS, Lemery-Chalfant K, & Goldsmith HH (2013). Genetic and environmental influences on rumination, distraction, and depressed mood in adolescence. Clinical Psychological Science, 1(3), 316–322. 10.1177/2167702612472884 [PubMed: 23956956]

Moore PS, Whaley SE, & Sigman M (2004). Interactions between mothers and children: Impacts of maternal and child anxiety. Journal of Abnormal Psychology, 113(3), 471–476. 10.1037/0021-843X.113.3.471 [PubMed: 15311992]

Morris AS, Cui L, Criss MM, & Simmons WK (2018). Emotion regulation dynamics during parent-child interactions: Implications for research and practice. In Cole PM & Hollenstein T (Eds.), Emotion Regulation: A Matter of Time (1st ed.). New York, NY: Routledge.

Nolen-Hoeksema S, Wisco BE, & Lyubomirsky S (2008). Rethinking rumination. Perspectives on Psychological Science, 3(5), 400–424. [PubMed: 26158958]

Palumbo RV, Marraccini ME, Weyandt LL, Wilder-Smith O, McGee HA, Liu S, & Goodwin MS (2017). Interpersonal autonomic physiology: A systematic review of the literature. Personality and Social Psychology Review, 21(2), 99–141. 10.1177/1088868316628405 [PubMed: 26921410]

Perry NB, & Calkins SD (2018). A biopsychosocial perspective on the development of emotion regulation across childhood. In Cole PM & Hollenstein T (Eds.), Emotion Regulation: A Matter of Time (1st Editio, pp. 3–30). New York, NY: Routledge.

Petersen AC, Crockett L, Richards M, & Boxer A (1988). A self-report measure of pubertal status: Reliability, validity, and initial norms. Journal of Youth and Adolescence, 17(2), 117–133. 10.1007/BF01537962 [PubMed: 24277579]

Pinheiro J, Bates D, DebRoy S, Sarkar D, & R Core Team. (2018). nlme: Linear and Nonlinear Mixed Effects Models. Retrieved from https://cran.r-project.org/package=nlme

Polanczyk GV, Salum GA, Sugaya LS, Caye A, & Rohde LA (2015). Annual research review: A meta-analysis of the worldwide prevalence of mental disorders in children and adolescents. Journal of Child Psychology and Psychiatry and Allied Disciplines, 56(3), 345–365. 10.1111/jcpp.12381

Rose AJ (2002). Co-rumination in the friendships of girls and boys. Child Development, 73(6), 1830–1843. 10.1111/1467-8624.00509 [PubMed: 12487497]

Schäfer JÖ, Naumann E, Holmes EA, Tuschen-Caffier B, & Samson AC (2017). Emotion regulation strategies in depressive and anxiety symptoms in youth: A meta-analytic review. Journal of Youth and Adolescence, 46(2), 261–276. 10.1007/s10964-016-0585-0 [PubMed: 27734198]

Sheeber L, Allen N, Davis B, & Sorensen E (2000). Regulation of negative affect during mother – child problem-solving interactions : Adolescent depressive status and family processes, 28(5), 467–479.

Shirtcliff EA, Dahl RE, & Pollak SD (2009). Pubertal development: Correspondence between hormonal and psychical development. Child Development, 80(2), 327–337. 10.1111/j.1467-8624.2009.01263.x.Pubertal [PubMed: 19466995]

Sroufe LA (1996). Emotional Development: The Organization of Emotional Life in the Early Years. Cambridge, UK: Cambridge University Press.

Tan PZ, Oppenheimer CW, Ladouceur CD, Butterfield RD, & Silk JS (2020). A review of associations between parental emotion socialization behaviors and the neural substrates of emotional reactivity and regulation in youth. Developmental Psychology, 56(3), 516–527. 10.1037/dev0000893 [PubMed: 32077721]

Timmons AC, Margolin G, Saxbe DE, Timmons AC, Margolin G, & Saxbe DE (2015). Physiological linkage in couples and its implications for individual and interpersonal functioning : A literature review. Journal of Family Psychology, 29(5), 720–731. [PubMed: 26147932]

Tooley MD, Carmel D, Chapman A, & Grimshaw GM (2017). Dissociating the physiological components of unconscious emotional responses. Neuroscience of Consciousness, 3(1), 1–11. 10.1093/nc/nix021

Tortella-Feliu M, Balle M, & Sesé Albert A (2010). Relationships between negative affectivity, emotion regulation, anxiety, and depressive symptoms in adolescents as examined through structural equation modeling. Journal of Anxiety Disorders, 24(7), 686–693. 10.1016/j.janxdis.2010.04.012 [PubMed: 20472383]

Ullsperger JM, & Nikolas MA (2017). A meta-analytic review of the association between pubertal timing and psychopathology in adolescence: Are there sex differences in risk? Psychological Bulletin, 143(9), 903–938. 10.1037/bul0000106 [PubMed: 28530427]

Van Lissa CJ, Keizer R, van Lier PAC, Meeus WHJ, & Branje S (2018). The role of fathers' versus mothers' parenting in emotion-regulation development from mid-late adolescence: Disentangling between-family differences from within-family effects. Developmental Psychology, 55(2), 377–389. [PubMed: 30570297]

Weisz JR, McCabe MA, & Dennig MD (1994). Primary and secondary control among children undergoing medical procedures: Adjustment as a function of coping style. Journal of Consulting and Clinical Psychology, 62(2), 324–332. 10.1037/0022-006X.62.2.324 [PubMed: 8201070]

Woody ML, Feurer C, Sosoo EE, Hastings PD, & Gibb BE (2016). Synchrony of physiological activity during mother-child Interaction: Moderation by maternal history of major depressive disorder. Journal of Child Psychology and Psychiatry, 57(7), 843–850. 10.1016/j.contraception.2015.12.017.Women [PubMed: 27090774]

Yap MBH, Schwartz OS, Byrne ML, Simmons JG, & Allen NB (2010). Maternal positive and negative interaction behaviors and early adolescents' depressive symptoms: Adolescent emotion regulation as a mediator. Journal of Research on Adolescence, 20(4), 1014–1043. 10.1111/j.1532-7795.2010.00665.x

Ziegert DI, & Kistner JA (2002). Response styles theory: Downward extension to children. Journal of Clinical Child and Adolescent Psychology, 31(3), 325–334. [PubMed: 12149970]

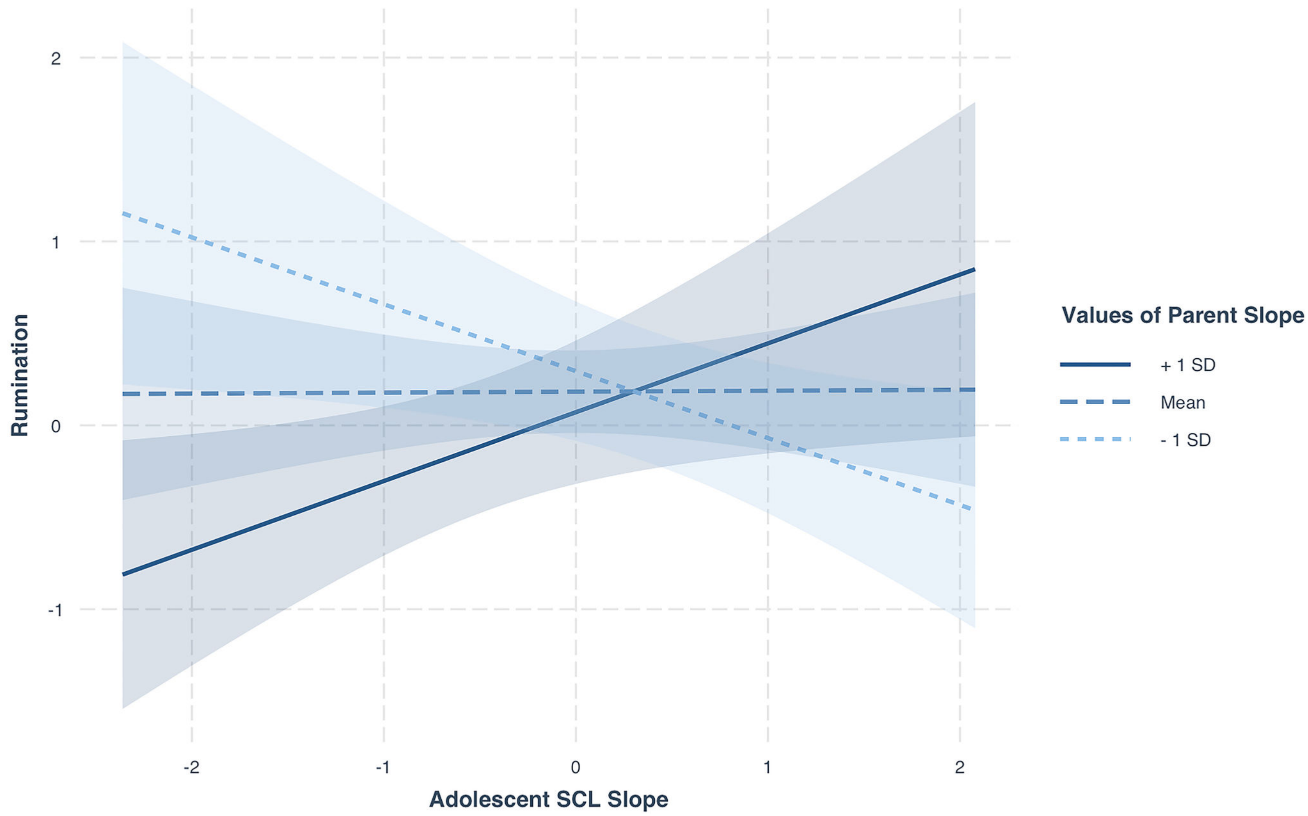

Figure 1.
Simple slopes analysis of mutual escalation and rumination
Note: SCL=Skin conductance level.

Table 1.

Means, standard deviations, and correlations of study variables with confidence intervals

Variable	*M*	*SD*	1	2	3	4	5	6	7
1. Child age	12.29	0.81							
2. Parent age	42.93	7.03	.14						
			[−.05, .33]						
3. Child race (% White)	69%	--	−.15	−.14					
(0=White; 1=nonWhite)			[−.33, .04]	[−.33, .05]					
4. Parent race (% White)	77%	--	−.16	−.16	.82**				
(0=White; 1=nonWhite)			[−.34, .04]	[−.34, .04]	[.74, .87]				
5.Socioeconomic status	7.20	3.02	.10	.32**	−.25*	−.30**			
			[−.10, .28]	[.14, .48]	[−.42, −.06]	[−.47, −.11]			
6. Pubertal status	3.57	1.02	.47**	.03	−.02	−.05	−.08		
			[.31, .61]	[−.17, .22]	[−.21, .18]	[−.25, .15]	[−.27, .12]		
7. Rumination	48.41	21.06	.16	−.21*	.07	.05	−.13	.07	
			[−.04, .34]	[−.39, −.02]	[−.13, .25]	[−.15, .24]	[−.32, .06]	[−.13, .26]	
8. Problem-solving	7.97	1.84	.13	−.08	−.04	−.04	−.07	−.03	.28**
			[−.07, .31]	[−.27, .12]	[−.23, .16]	[−.24, .16]	[−.26, .13]	[−.23, .16]	[.09, .45]

Note. N=97. M and *SD* are used to represent mean and standard deviation, respectively. Values in square brackets indicate the 95% confidence interval for each correlation. The confidence interval is a plausible range of population correlations that could have caused the sample correlation (Cumming, 2014).

* indicates $p < .05$.

** indicates $p < .01$. Pubertal status=PDS (Shirtcliff et al., 2009); Rumination=CRSS rumination subscale; Problem-solving=RSQ problem-solving subscale.

Table 2.

Model relative fit statistics and comparisons

	Model	N_{obs}	N_{dyads}	*df*	*AIC*	*BIC*	*−2LL*	*Test*	*L.Ratio*	*p*
1	Model for the means	5820	97	7	55037.51	55084.20	55023.52	--	--	--
2	Fixed effect of time	5820	97	9	54950.71	55010.73	54932.70	1 vs. 2	90.80	<.001
3	Random effect of time	5820	97	16	53489.92	53596.62	53457.92	2 vs. 3	1474.79	<.001
4	Fixed lagged effect	5432	97	18	48763.48	48882.29	48727.48	--	--	--
5	Fixed cross-lagged effect	5432	97	20	48762.34	48894.34	48722.34	4 vs. 5	5.14	0.076
6	Random cross-lagged effect	5432	97	25	48744.03	48909.03	48694.02	5 vs. 6	28.30	<.001

Table 3.

Final dyadic model fixed effects

	Parameter	Est(SE)	95% CI	*p*
Mothers	Intercept (γ_{00M})	**21.50(1.28)**	**19.00, 24.00**	**<.001**
	Time (γ_{10M})	−0.02(0.11)	−0.24, 0.20	.874
	Lag (γ_{20M})	**0.46(0.02)**	**0.43, 0.49**	**<.001**
	Adolescent to mother cross-lag (γ_{30M})	−0.02(0.02)	−0.05, 0.01	.210
Adolescents	Intercept (γ_{00D})	**31.80(1.75)**	**28.30, 35.20**	**<.001**
	Time (γ_{10D})	0.20(0.11)	−0.01, 0.41	.063
	Lag (γ_{20D})	**0.33(0.02)**	**0.30, 0.37**	**<.001**
	Mother to adolescent cross-lag (γ_{30D})	0.04(0.28)	−0.02, 0.09	.093

Table 4.

Regression results of mutual escalation models predicting adolescent emotion regulation

	Adolescent Self-Reported Rumination			**Adolescent Self-Reported Problem-Solving**			**Physiological Regulation**		
Predictors	***Estimates***	***CI***	***p***	***Estimates***	***CI***	***p***	***Estimates***	***CI***	***p***
(Intercept)	0.18	−0.04–0.40	0.114	0.10	−0.14–0.33	0.420	0.10	−0.14–0.33	0.409
Age (centered)	0.20	−0.00–0.40	0.054	0.15	−0.06–0.37	0.147			
Parent-to-adolescent cross lag	0.05	−0.26–0.36	0.730	−0.01	−0.34–0.31	0.930	0.04	−0.28–0.37	0.788
Parent slope of time	−0.11	−0.42–0.20	0.480	−0.05	−0.38–0.28	0.761	0.13	−0.20–0.45	0.446
Adolescent slope of time	0.01	−0.22–0.23	0.958	−0.11	−0.35–0.13	0.356	0.01	−0.23–0.25	0.918
Mutual escalation (parent-adolescent slope interaction)	**0.37**	**0.14–0.59**	**0.002**	0.19	−0.05–0.43	0.114	0.20	−0.04–0.43	0.103
Observations	96			95			96		
R^2/ R^2adjusted	0.14 / 0.09			0.06 / 0.01			0.04 / −0.01		

Note: All variables are standardized for ease of interpretation. Values in bold are significant at $p<.05$.