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Self- and co-regulation of physiological activity during mother-daughter interactions: The role of adolescent non-suicidal self-injury

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Background: Non-suicidal self-injury (NSSI) is a significant public health concern that is thought to increase risk for future self-injurious behaviors, including suicide attempts. Notably, NSSI is especially prevalent among adolescents, which underscores a critical need to identify modifiable risk factors that could be targeted to reduce future risk. The current study examined self- and co-regulation of physiological responses during mother-daughter interactions in adolescent girls with and without a history of NSSI. **Methods:** Participants were 60 girls aged 13–17 with (n = 27) and without (n = 33) a history of NSSI and their mothers. Adolescents and their mothers completed positive and negative interaction tasks during which physiological reactivity was assessed via respiratory sinus arrhythmia (RSA). **Results:** Using Actor-Partner Interdependence Modeling (APIM), we found that adolescents with an NSSI history demonstrated a higher RSA setpoint than adolescents without this history during the negative, but not positive, interaction task. In addition, there were differences in co-regulation during the negatively valenced interaction, such that mothers of daughters with NSSI were more reactive to fluctuations in their daughters' RSA than mothers of daughters without an NSSI history. **Conclusions:** These findings highlight intra- and interpersonal aspects of physiological dysregulation associated with NSSI that could provide promising targets of intervention to reduce future risk in adolescent girls. **Keywords:** Non-suicidal self-injury; mother-daughter interaction; respiratory sinus arrhythmia; adolescence.

Introduction

Non-suicidal self-injury (NSSI) is defined as purposeful, self-inflicted harm without the intent to die (Nock, Joiner, Gordon, Lloyd-Richardson, & Prinstein, 2006). As a transdiagnostic behavior, NSSI co-occurs with myriad forms of psychopathology and can be present in the absence of psychiatric diagnoses (Nock et al., 2006). NSSI is also highly comorbid with suicidal thoughts and behaviors (STB) and increases risk for future episodes of NSSI and suicide attempts (Ribeiro et al., 2016). Of particular concern, rates of NSSI are especially high during adolescence with approximately 18% of adolescents reporting lifetime engagement in the behavior (Swannell, Martin, Page, Hasking, & St John, 2014). Indeed, theorists propose that NSSI may function as a maladaptive emotion regulation strategy employed to manage elevated emotional reactivity to stressful social experiences (Hasking, Whitlock, Voon, & Rose, 2016; Nock & Prinstein, 2004; Selby & Joiner, 2009).

There is clear evidence for emotion regulation deficits in youth with a history of NSSI (Brausch, Clapham, & Littlefield, 2022; Wolff et al., 2019). These relations appear to be at least partially independent of co-occurring psychopathology (e.g., depression, features of borderline personality disorder; Glenn & Klonsky, 2013; Perez, Venta, Garnaat, & Sharp, 2012). Despite the strengths of this research, it has focused almost exclusively on broad-based measures, and little is known about self-(dys)regulation of emotions and physiology that may occur on a moment-to-moment basis during social interactions that is proposed to be a key aspect of NSSI risk. In this regard, social interactions with parents may be particularly important because the dramatic increase in NSSI from childhood to adolescence corresponds with the increase in emotional intensity of parent–child conflict that youth experience during this developmental period (Laursen, Coy, & Collins, 1998). As with research on emotion dysregulation, there is a large body or research linking specific parent factors (e.g., lack of support and higher levels of invalidation and adolescent NSSI risk; for a review, see James & Gibb, in press). In addition to these broad-based influences, however, parents may help to regulate their child's level of physiological activity (co-regulation). Indeed, over the course of development and countless interactions, family members shape each other's behavioral, affective, and physiological response (e.g., see Patterson et al., 1984). This said, little is known about how self- and co-regulation processes occurring during actual parent-adolescent interactions may differ in families of adolescents with a history of NSSI. To address this gap in the literature, we examined self- and co-

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regulation of physiological activity during standardized positive and negative mother-daughter interactions among dyads with and without a history of adolescent NSSI.

We focused on respiratory sinus arrhythmia (RSA), which is a marker of autonomic nervous system functioning and reflects parasympathetic cardiac vagal control (e.g., Berntson et al., 1997; Porges, 2007; Porges & Doussard-Roosevelt, 1996). RSA is also thought to reflect the capacity for emotion regulation (Beauchaine, 2001, 2012; Porges & Doussard-Roosevelt, 1996), and can be estimated from high-frequency heart rate variability (HRV). Higher resting RSA is thought to indicate a greater capacity to flexibly and adaptively respond to stress (Thayer & Lane, 2001). Researchers have also examined RSA reactivity, which reflects vagal regulation of cardiac activity in response to a stress. In healthy individuals, a moderate decrease in RSA (i.e., RSA withdrawal) in response to emotional stimuli or interpersonal stress is viewed as an adaptive physiological response to environmental challenges or stress (Beauchaine, 2001; Lovallo, 2015) and is associated with an increased capacity for emotion regulation (Gentzler, Santucci, Kovacs, & Fox, 2009; Porges & Doussard-Roosevelt, 1996). Given that NSSI often functions as a (maladaptive) strategy for regulating emotional responses to stressors (Edmondson, Brennan, & House, 2016; Klonsky & Glenn, 2009) and that interpersonal stress may be especially salient during adolescence (Kaess et al., 2020), we sought to clarify the extent to which resting RSA and RSA reactivity differ in adolescents with and without a history of NSSI. Importantly, we also examined RSA in adolescents' mothers, which is important for the study of co-regulation.

To date, research examining associations between adolescents' engagement in NSSI and RSA has yielded mixed results (for a review, see, Kaess et al., 2021). For example, although there is some evidence that adolescent girls with a history of NSSI demonstrate lower resting RSA than girls without this history (Crowell et al., 2005), other research has found no differences in RSA among adolescents with and without a history of NSSI (Koenig et al., 2017). Similar mixed results have been observed in terms of RSA reactivity. For example, two studies have shown that girls who engage in self-injury demonstrate emotion dysregulation in the form of excessive reductions in RSA from baseline in response to emotional laboratory-based tasks, including a sad mood induction (Crowell et al., 2005) and mother-daughter conflict discussion (Crowell et al., 2017). Conversely, other research finds that adolescents who report NSSI demonstrate less RSA withdrawal in responses to psychosocial stress than adolescents without NSSI (Koenig et al., 2022).

Importantly, however, studies that focus only on adolescents' responses during dyadic interactions may fail to capture important co-regulation effects that may be occurring. As noted above, these co-regulation effects are a key component of parent–child interactions. In the case of RSA, co-regulation occurs when RSA levels in one member of a dyad predicts subsequent changes in the other person's RSA. Co-regulation can thus be adaptive or maladaptive depending on context and whether co-regulation leads to concordant (i.e., both partners exhibit RSA withdrawal in response to each other) or discordant responding (i.e., one partner exhibits RSA withdrawal in response to their partner). There is some research suggesting greater concordance in healthy individuals is indicative of well-being (Marsh, Beauchaine, & Williams, 2007) though others have suggested that lower concordance may reflect active self-regulation and/or better emotion regulation skills (Mauss, Levenson, McCarter, Wilhelm, & Gross, 2005). This area of research is still developing, and little is known about how self- and co-regulatory responding may differ for youth who engage in NSSI. Specifically, although there is some evidence that maternal behavior may impact adolescent RSA during mother-adolescent interactions, including adolescents with a history of self-injury (suicidal or non-suicidal self-injury; Crowell et al., 2014, 2017), we are not aware of any prior study that has examined self- and co-regulation of both mother and adolescent RSA in dyads with adolescent NSSI.

In the current study, we examined dynamic patterns of change in adolescents' and mothers' RSA reflecting self- and co-regulation during standardized laboratory-based interaction tasks. Further, to assess potential contextual influences, participants completed both a positive (i.e., vacation planning) and negative (i.e., conflict resolution) discussion. Based on evidence that girls exhibit greater reactivity to interpersonal stress than boys (Rose & Rudolph, 2006), we focused specifically on mother-daughter pairs to reduce heterogeneity within our sample. We utilized a dynamical systems approach involving Actor Partner Interdependence Modeling (APIM; Kenny, Kashy, & Cook, 2006), which integrates morphostatic (stability) and morphogenetic (change) dyadic processes to determine dynamic changes within a system (Butler & Randall, 2013). Conceptually, adolescents and their mothers are viewed as systems that have homeostatic setpoints of RSA. Dynamical systems modeling, therefore, detects (a) how each individual responds to contextual shifts (e.g., positive versus negative discussion topics) as they also strive to maintain homeostasis, and (b) how the capacity to maintain that homeostatic setpoint may be affected by individual factors (e.g., NSSI). Additionally, this type of statistical modeling provides self-regulatory (i.e., actor) and co-regulatory (i.e., partner) effects, and can be used to determine group differences in these effects based on adolescents' NSSI history. It is, therefore, effective in distinguishing between self- and co-regulatory influences on homeostatic

setpoint maintenance and dynamic changes in physiology within the dyadic system.

Based on previous research suggesting deficits in emotion regulation in adolescents with NSSI (Brausch et al., 2022; Brausch & Woods, 2019), we predicted that adolescent girls with a history of NSSI, compared to those without NSSI, would exhibit less self-regulation of RSA (weaker actor effects), particularly during the negatively valenced interaction. Although we also examined self-regulation among mothers, these analyses were more exploratory. In terms of co-regulation, drawing upon evidence of interpersonal influences between mother-daughter dyads with adolescent self-injury (Crowell et al., 2017), we predicted that dyads in which the daughter reported NSSI would exhibit more co-regulation of RSA (stronger partner effects) than dyads without adolescent NSSI.

Methods

Participants

Participants were 61 mother-daughter dyads recruited from the community based on girls' NSSI history through advertisements on social media and brochures placed in the community (e.g., gyms, hair salons, medical offices, and therapist waiting rooms). All daughters were required to be between the ages of 13 and 17 years and were eligible for the study if they lived with their participating parent at least 50% of the time and did not have a developmental disorder or learning disability that would make it difficult to complete the questionnaires or tasks. To meet criteria for inclusion in the NSSI group, girls had to report a history of self-injurious cutting behavior (at least two distinct episodes) without intent to die (n = 27). One additional adolescent was excluded from analyses due to ambiguous engagement in NSSI (i.e., discrepant reports from mother and adolescent that called into question whether the adolescents' engagement in a self-harm behavior [skin picking] was deliberate). The remaining 33 participants comprised the control group. These participants had no lifetime history of NSSI. Therefore, the final sample comprised 60 adolescents (27 with NSSI; 33 without NSSI). Adolescents were, on average, 15.23 years (SD = 1.30). Of the adolescents, 78.7% were White, 6.6% were African American/Black, 4.9% were Asian, and 9.8% were multiracial or from another racial group. Additionally, 8.5% of adolescents were Hispanic. Of the mothers, 90% were White, 3.3% were African American/Black, 1.7% were Asian, and 5.1% were multiracial or from another racial group. Additionally, 5.1% of mothers identified as Hispanic. Demographic and clinical characteristics of each group are provided in Table 1.

Measures

Adolescents' NSSI history. Adolescents' NSSI was first identified during a phone screen with the adolescents' mothers, in which mothers were asked, 'Has your daughter ever hurt herself without wanting to die, such as cutting or burning herself?' This screening question was followed by questions about method, recency, and frequency of NSSI. During the laboratory visit, adolescents' lifetime NSSI was further assessed using the Self-Injurious Thoughts and Behaviors Interview (SITBI; Nock, Holmberg, Photos, & Michel, 2007). Specifically, adolescents' NSSI history was probed with the question 'Have you ever actually engaged in NSSI?' where NSSI is defined as 'purposely hurting yourself without wanting to die.' Twenty-seven adolescents reported at least two lifetime NSSI episodes (Range: 2–400; *Median* = 9) with 15 adolescents reporting past year NSSI (Range: 5 days–

Table 1 Descriptive statistics

	NSSI (n = 27)	No NSSI (n = 33)	$r_{\text{effect size}}$
Adolescent age	15.20 (1.37)	15.22 (1.25)	−.01
Mother age	45.15 (7.39)	42.40 (7.83)	.18
Adolescent race (% White)	77.8%	78.8%	−.01
Mother race (% White)	92.6%	84.8%	.08
Income	$60,001–$65,000	$70,001–$75,000	−.09
Adolescent current MDD Dx	37.0%	6.1%	.39*
Adolescent lifetime MDD Dx	85.2%	42.4%	.44**
CDI	19.11(8.80)	10.24 (7.19)	.49**
MASC	60.95 (18.10)	45.84 (14.95)	.42**
BPFSC	36.41 (7.64)	26.24 (6.04)	.60**
Adolescent current SI	37.0%	9.1%	.34*
Adolescent lifetime SI	81.5%	37.5%	.43*
Adolescent lifetime SA	14.8%	3.0%	.21
BDI-II	10.38 (8.79)	10.55 (10.86)	.11
BAI	10.38 (8.79)	9.48 (10.40)	.05
Mother lifetime SA	22.2%	21.2%	.01
Mother lifetime NSSI	14.8%	12.1%	.04
Adolescent RSA – Rest	7.21 (0.83)	6.93 (1.05)	.15
Adolescent RSA – Vacation	7.30 (0.79)	6.97 (1.06)	.17
Adolescent RSA – Conflict	7.10 (0.90)	6.87 (1.04)	.12
Mother RSA – Rest	5.81 (1.06)	6.14 (1.41)	−.13
Mother RSA – Vacation	5.70 (1.10)	6.05 (1.14)	−.16
Mother RSA – Conflict	5.71 (1.08)	5.99 (1.23)	−.12

BAI, Beck Anxiety Inventory; BDI, Beck Depression Inventory; BPFSC, Borderline Personality Features Scale for Children; CDI, Children's Depression Inventory; Dx, diagnosis; MASC, Multidimensional Anxiety Scale for Children; MDD, Major Depressive Disorder; SA, suicide attempt; SI, suicidal ideation.
*p < .01. **p < .001.

4 years). All 27 girls reported cutting themselves at least twice, eight (30%) of whom also reported additional NSSI methods (e.g., burning, hitting self on purpose, and scrapping skin).

Discussion paradigm. Adolescents and their mothers completed a standardized Discussion Paradigm that included positively- and negatively valenced interactions (Robin & Foster, 1989). During this paradigm, mother-adolescent dyads first participated in a 2-min resting baseline task during which they viewed a nature video featuring landscape footage from Olympic National Park. Second, dyads engaged in a 4-min Vacation Planning task in which they were asked to plan a 'dream vacation' for just the two of them. Third, dyads completed a 6-min Conflict Resolution task centered around a selected topic from each dyad's responses to an Issues Checklist that was completed separately by both the adolescent and mother prior to beginning the Discussion Paradigm. This Issues Checklist presents typical areas of disagreement (e.g., lying, homework, chores, etc.). Participants indicate both the frequency and intensity of their conflicts over each presented domain. The topic mutually endorsed with the highest frequency and intensity ratings was selected for the Conflict task, and mother-adolescent dyads were asked to talk about the topic, describe a recent disagreement, and attempt to resolve it. Additional information about the paradigm is presented in the Supporting Information (Section 1.1 and Figure S1).

RSA signal recording and processing. During each phase of the Discussion Paradigm, electrocardiogram (ECG) and respiration data were obtained simultaneously from adolescents and their mothers using Biopac BioNomadix wireless systems and recorded with Acqknowledge v4.2 software. ECG was recorded via a standard 3-electrode (lead II) set-up and ECG data were sampled at 1000 Hz. Respiration was recorded from a respiratory belt secured around participants' chests. Paralleling existing research (Wilson et al., 2016), RSA was estimated using high-frequency heart rate variability (HF-HRV; Berntson et al., 1997). See Supporting Information (Section 1.2) for additional information about RSA processing.

The data were binned into 30-s epochs for each of the three stages of the Discussion Paradigm, which were used for the APIM analyses (Rest: four epochs; Vacation: eight epochs; Conflict: 12 epochs). To examine mean levels of RSA during each task, values were averaged across the 30-s epochs within each task, resulting in separate RSA averages for the 2-min baseline rest period (average of four epochs), 4-min Vacation task (average of eight epochs), and the 6-min Conflict task (average of 12 epochs).

Symptoms. To more fully characterize the sample, adolescents' current and lifetime episodes of major depressive disorder were assessed using the Schedule for Affective Disorders and Schizophrenia for School-Age Children – Present and Lifetime Version (K-SADS-PL; Kaufman et al., 1997). Adolescents' symptoms of depression and anxiety were assessed using the Children's Depression Inventory (CDI; Kovacs, 1981) and the Multidimensional Anxiety Scale for Children (MASC; March, Parker, Sullivan, Stallings, & Conners, 1997). The CDI and MASC demonstrated excellent internal consistency (αs = .91 and .91, respectively). Adolescents' traits of borderline personality disorder were assessed using the Borderline Personality Features Scale for Children – Short Version (BPFSC-11; Sharp, Steinberg, Temple, & Newlin, 2014), which demonstrated good internal consistency (α = .85). Mothers' symptoms of depression and anxiety were assessed using the Beck Depression Inventory-II (BDI-II; Beck, Steer, & Brown, 1996) and the Beck Anxiety Inventory (BAI; Steer & Beck, 1993). Both measures exhibited excellent internal consistency (αs = .92 and .92, respectively). Adolescents' and mothers' current and lifetime STBs and mothers' current and lifetime NSSI were assessed using the Self-Injurious Thoughts and Behaviors Interview (SITBI; Nock et al., 2007).[1]

Procedure and ethical considerations

Participants were screened for eligibility based on NSSI history on the phone; eligible participants invited to the lab to complete the study. During the laboratory visit, participants were fully informed about the process and purpose of the study. After providing written consent/assent, adolescents and mothers separately completed a series of interview and questionnaire assessments, including the Issues Checklist. Then, dyads completed the standardized Discussion Paradigm during which ECG data were simultaneously and continuously recorded. Adolescents and mothers were compensated $30 and $25, respectively. Each dyad was given a $10 gas card. All study procedures were approved by Binghamton University's Institutional Review Board.

Analytic plan

We employed a dynamical systems approach using Actor Partner Interdependence Modeling (APIM; Kenny et al., 2006) to examined both self-regulation (i.e., actor) and co-regulation (i.e., partner) effects on patterns of change in adolescents' and mothers' RSA during the Discussion Paradigm. Specifically, we conducted a series of repeated-measures change-as-outcome Actor Partner Interdependence Models (RM-APIM) in which ΔRSA ($RSA_{t+1} - RSA_t$) served as the primary outcome, with adolescents' NSSI history included as a moderator and separate models conducted for the Vacation and Conflict discussions. This approach allowed us to examine whether adolescents' history of NSSI moderated daughters' or mothers' (a) RSA setpoint during each discussion, (b) self-regulation of RSA during each discussion (trajectory and rate of actor effects; i.e., stability of RSA across each 30 s epoch), and/or (c) co-regulation of RSA during each discussion (trajectory and rate of partner effects; i.e., the degree to which one person's RSA during any given 30-s epoch predicts change in their partner's RSA from that same 30-s epoch to the subsequent 30-s epoch). Predictors were grand mean centered to improve interpretability and reduce multicollinearity. These models are depicted in Figure 1. Additional information about these analyses are provided in the Supporting Information (Section 1.4).[2]

Results

The results of the RM-APIM models are presented in Figure 2. Full details of the analyses from these models during Vacation and Conflict are presented in Table 2. Focusing first on adolescents' and mothers' RSA setpoints (intercepts) during the interaction tasks, the only significant moderation effect was observed for adolescents' RSA setpoint

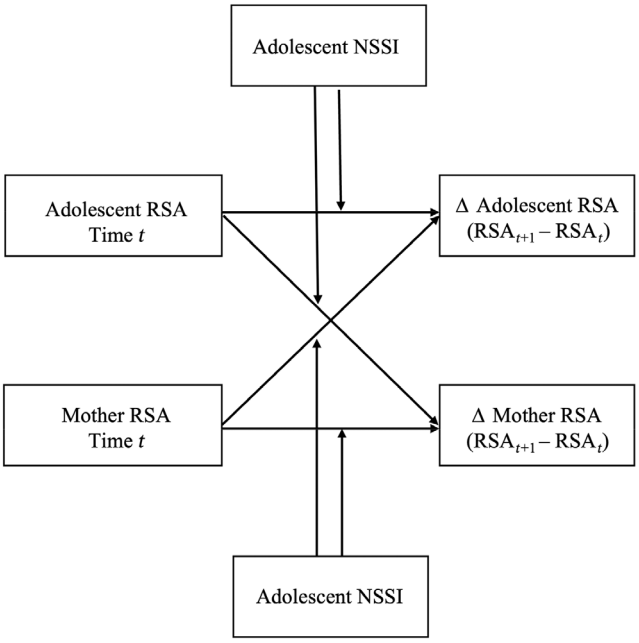

Figure 1 Conceptual model of these repeated-measures actor-partner interdependence models

during Conflict ($B = .53$, $p = .04$), suggesting that adolescents with NSSI demonstrated a higher RSA setpoint than adolescents without NSSI.

Turning next to self-regulatory dynamics during the interactions, significant negative actor effects for adolescents and their mothers were observed during Vacation (Adolescent: $B = -.80$, $p < .001$; Mother: $B = -.86$, $p < .001$) and Conflict (Adolescent: $B = -.88$, $p < .001$; Mother: $B = -.84$, $p < .001$), suggesting that, overall, adolescents and their mothers were attracted to their own RSA setpoints and demonstrated self-regulation (i.e., stability of RSA within the *intra*personal system). Of note, NSSI history did not moderate the actor effects in either task (lowest $p = .37$). Finally, in terms of co-regulation, adolescents' NSSI history moderated the partner effect of adolescent RSA on changes in mothers' RSA during Conflict ($B = -.24$, $p < .01$) such that co-regulation (i.e., *inter*personal influence on change in RSA) was present for dyads with adolescent NSSI ($B = -.17$, $p = .003$), but not dyads without adolescent NSSI ($B = .06$, $p = .31$). Specifically, for dyads in which the adolescent engaged in

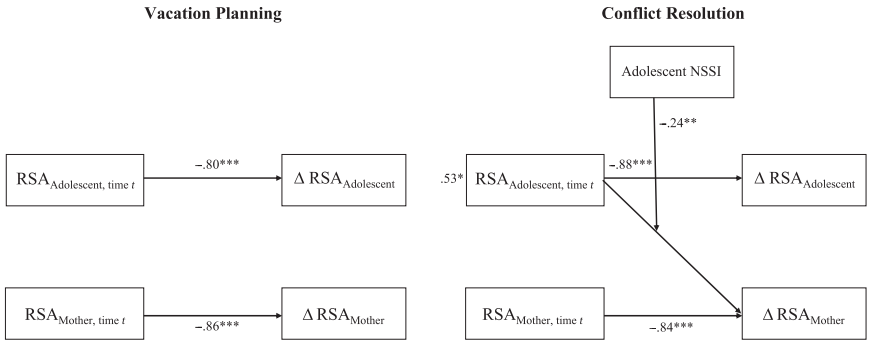

Figure 2 Repeated-measures actor-partner interdependence models with change in RSA as the primary outcome for Vacation (left) and Conflict (right). RSA = Respiratory sinus arrhythmia. Values represent unstandardized betas, and only significant effects are depicted. Significant NSSI moderation of the setpoint is shown to the left of the time *t* RSA box. *$p < .05$. **$p < .01$. ***$p < .001$.

Table 2 Repeated-measures actor-partner interdependence model results of change in RSA

	Vacation			Conflict		
	t	*B*	95% CI	*t*	*B*	95% CI
Adolescent						
Intercept	−1.10	−0.16	−0.45, 0.14	−1.54	−0.27	−0.62, 0.08
Intercept × NSSI	1.83	0.39	−0.04, 0.83	2.10*	0.53	0.02, 1.05
Actor effect	−13.20***	−0.80	−0.92, −0.68	−15.82***	−0.88	−0.99, −0.77
Actor effect × NSSI	0.02	0.00	−0.20, 0.20	−0.13	−0.01	−0.17, 0.15
Partner effect	−0.16	−0.01	−0.14, 0.12	−0.41	−0.02	−0.12, 0.08
Partner effect × NSSI	0.53	0.05	−0.14, 0.24	−0.28	−0.02	−0.18, 0.13
Mother						
Intercept	0.68	0.14	−0.27, 0.54	0.86	0.17	−0.22, 0.55
Intercept × NSSI	−0.93	−0.27	−0.87, 0.32	−0.84	−0.23	−0.80, 0.33
Actor effect	−12.62***	−0.86	−0.99, −0.72	−15.75***	−0.84	−0.95, −0.74
Actor effect × NSSI	−0.90	−0.09	−0.28, 0.10	−0.52	−0.04	−0.20, 0.12
Partner effect	1.57	0.09	−0.02, 0.21	1.61	0.09	−0.02, 0.20
Partner effect × NSSI	−0.60	−0.06	−0.25, 0.13	−3.01**	−0.24	−0.40, −0.08

CI, Confidence Interval; NSSI, Non-suicidal self-injury; RSA = Respiratory sinus arrhythmia.
*$p < .05$. **$p < .01$. ***$p < .001$.

NSSI, higher levels of adolescent RSA during a given 30-s epoch predicted mothers' more rapid return to their RSA setpoint in the subsequent 30-s epoch. This effect was maintained after statistically controlling for the potential impact of mothers' and adolescents' current symptoms of depression and anxiety, as well as adolescents' symptoms of borderline personality disorder (all ps $\leq .01$). None of the other main or interactive partner effects were significant during Vacation or Conflict (lowest $p = .12$).

Discussion

The goal of this study was to determine whether adolescents with an NSSI history exhibit atypical or disrupted physiological (RSA) responses during positively- and negatively valenced mother-daughter interactions. In addition to examining the adolescents themselves, we also examined physiological responses in their mothers, to get a fuller picture of the dynamic reactions that may be disrupted during mother-daughter interactions. This approach allowed us to examine self- and coregulation of physiological activity during positive (Vacation) and negative (Conflict) mother-daughter interactions and how these dynamics may be impacted by adolescents' NSSI.

There were two notable differences associated with adolescents' NSSI. First, during Conflict, but not Vacation, adolescents with an NSSI history exhibited a higher RSA setpoint than adolescents without NSSI. In the context of interpersonal stress (e.g., during a conflict discussion with a parent who is aware of one's history of NSSI), a higher RSA homeostasis may reflect failure to engage an adaptive physiological response to environmental challenges or stress (i.e., RSA withdrawal; Beauchaine, 2001; Lovallo, 2015). Given that moderate RSA withdrawal in response to stress is associated with an increased capacity for emotion regulation (Gentzler et al., 2009; Koenig et al., 2017; Porges & Doussard-Roosevelt, 1996), the current results align with theoretic models of NSSI, suggesting that those who engage in NSSI exhibit elevated emotional reactivity to stressful social experiences (Hasking et al., 2016; Selby & Joiner, 2009).

The second key finding was that mothers of daughters with NSSI were more reactive to fluctuations in their daughters' RSA (partner effect) than mothers of daughters with no history of NSSI, demonstrating a more rapid return to their RSA setpoint. Again, this effect was only observed during Conflict and not Vacation. This pattern of co-regulation indicates that mothers of adolescents with NSSI have a greater response to their daughters' physiological arousal during negatively valenced discussions than control mothers. This result is especially noteworthy given the lack of overall co-regulatory influences for RSA in these mother-daughter dyads. That is, with the exception of the impact of NSSI daughters' RSA on their mothers' RSA during Conflict, neither partners' change in RSA was influenced by the other.

One possible explanation for this exception is that these mothers, aware of their daughters' history of NSSI, are more likely to attempt to adjust their physiological arousal prompted by a negatively valenced discussion, perhaps in an effort to reduce their daughters' distress. This explanation is consistent with the NSSI Family Distress Cascade Theory (Waals et al., 2018), which suggests that, following disclosure of NSSI, parents may demonstrate increased hypervigilance and heightened efforts to control their child's behavior as a result of their own experience of guilt, fear, or shame. Parents of youth who engage in NSSI also report increased caution during interactions with their child for fear of triggering more NSSI (Oldershaw, Richards, Simic, & Schmidt, 2008). Thus, given that mothers of adolescents with an NSSI history also reported increases in anxiety during Conflict, this interpersonal effect may reflect mothers' heightened attunement to their daughters' emotional state, as well as elevated sensitivity to a normative, albeit negatively valenced, discussion with their daughter. Furthermore, although these mothers' hastened return to their physiological setpoint may model effective emotion regulation for their distressed daughters, this behavior is also restrictive and may yield long-term consequences. For example, this seemingly protective response may also have implications for these adolescents' ability to learn to tolerate emotional or physiological distress from normative interpersonal conflict independently, potentially increasing future risk as those who engage in NSSI are often characterized by heightened affective reactivity (Hasking et al., 2016; Nock & Prinstein, 2004; Selby & Joiner, 2009). Future research that includes behavioral correlates is necessary to determine whether mothers' return to their physiological setpoint corresponds with their behavioral responses during negatively valenced interaction.

Strengths of the current study include the assessment of RSA during actual mother-daughter interactions, the use of both positively- and negatively valenced interactions, the specific focus on NSSI rather than self-injurious behaviors more generally, and the inclusion of adolescents reporting psychopathology and STBs across both groups. The decision to focus specifically on NSSI and to include adolescents with psychopathology and STBs in both groups was made to increase the specificity of our findings to NSSI by accounting for other potential sources of distress (e.g., suicidal thoughts), though there were still some group differences in these factors.

Nonetheless, several limitations warrant discussion. The primary limitation of the current study is its cross-sectional design. We are, therefore, unable to determine whether these disruptions in

physiology are a risk factor for, and/or consequence of, adolescent NSSI. Second, although our sample size is comparable to that of other studies testing similar models (e.g., Balderrama-Durbin et al., 2021; McKillop & Connell, 2018), we may have been underpowered to detect some moderation effects. Nonetheless, the magnitude of the nonsignificant NSSI moderation of actor and partner effects was quite small ($r_{effect\ size} \leq .03$), suggesting that they may not be clinically significant even if a larger sample size made them statistically significant. Third, some characteristics of our sample may limit the generalizability of our findings. For example, because we limited our sample to mother-daughter dyads, it remains unclear whether similar patterns of physiology would be observed in father-son dyads and/or dyads of opposite genders. In addition, mothers in the present study were aware of their daughters' NSSI and future research including mothers with and without knowledge of their daughters' NSSI is necessary to assess whether the current findings are a function of adolescents' NSSI or their mothers' awareness the NSSI. Finally, most of the participants enrolled in the current study identified as non-Hispanic and White. Thus, it remains unclear whether these results would generalize to more diverse populations.

Conclusion

The current study suggests that adolescent NSSI is associated with differences in regulation of physiological activity (RSA) specifically within negative, but not positive, mother-daughter interactions. In these negative interactions, adolescents with a history of NSSI, compared to adolescents with no NSSI history, exhibit a higher RSA setpoint and their mothers are more reactive to changes in their daughter's RSA, showing a quicker return to their RSA setpoint following RSA increases in their daughters. This pattern of results suggests these mothers are particularly sensitive to the physiological experience of their daughters and adjust by restricting their own physiological response. If replicated and extended in longitudinal research, these findings could inform a new generation of prevention and intervention efforts by providing specific targets for disrupting broader mechanisms of risk, like difficulties with emotion regulation, to reduce future NSSI risk. Such efforts may focus upon (i) further strengthening adolescents' self-regulatory strategies for tolerating emotional or physiological distress in response to stressful or conflictual social interactions, (ii) empowering mothers' to model self-regulation during and after conflict rather than attempting to de-escalate the situation or reduce their daughters' distress, and (iii) teaching adolescents and their mothers to effectively problem solve together so that they feel prepared to resolve conflict within the relationship and can anticipate reconciliation.

Supporting information

Additional supporting information may be found online in the Supporting Information section at the end of the article:

Figure S1. Timeline of discussion paradigm.
Figure S2. Adolescents' self-reported levels of sadness and anxiety as a function of adolescents' NSSI history across the Discussion Paradigm.
Figure S3. Mothers' self-reported levels of sadness and anxiety as a function of adolescents' NSSI history across the Discussion Paradigm.
Figure S4. Participants' mean RSA levels during the Discussion Paradigm.
Table S1. Results of repeated measures ANOVAs examining overall mood.
Table S2. Results of repeated measures ANOVAs examining overall levels of RSA.
Table S3. Repeated-Measures Actor Partner Interdependence Model Results of Change in RSA.

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Key points

- This study examined self- and co-regulation of physiological responses during mother-daughter interactions in adolescent girls with and without NSSI.
- Girls with an NSSI history demonstrated a higher RSA setpoint than girls without an NSSI history during negatively valenced interaction.
- Mothers of daughters with NSSI exhibited greater physiological responsivity to changes in their daughters' RSA than mothers of daughters without an NSSI history.
- These findings highlight intra- and interpersonal aspects of physiological dysregulation associated with NSSI that could provide promising intervention targets.

Endnotes

1. As part of the larger study, we also assessed levels of state sadness and anxiety in daughters and mothers after each phase of the Discussion Paradigm. Details of these assessments and analyses are reported in Sections 1.3 and 2.1 of the Supporting Information and depicted in Table S1 and Figures S2 and S3.
2. For interested readers, analyses examining overall levels of adolescents' and mothers' RSA during the Discussion Paradigm are presented in Section 2.2, Table S2, and Figure S4 of the Supporting Information and APIM analyses of the Rest phase of the Discussion Paradigm are provided in Section 2.3 and Table S3 of the Supporting Information.

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