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Respiratory sinus arrhythmia as a dyadic protective factor in the transition to parenthood

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Abstract

Considerable heterogeneity has been observed in couples' adjustment to the transition to parenthood (TTP). One potential yet understudied predictor of emotional adjustment to the TTP is the new parents' capacity for regulation. A widely accepted biological marker of this capacity is respiratory sinus arrhythmia (RSA), which is closely tied to parasympathetic activation. In the present work, we sought to examine the role of tonic RSA and RSA reactivity as possible protective dyadic factors in the TTP. As part of a larger study, we recruited a sample ($N = 100$) of TTP couples. At 15 weeks postpartum, the couples took part in a lab session during which their RSA was assessed both at rest (tonic RSA) and during four affiliative dyadic interactions (RSA reactivity). Following this session, couples completed daily diaries over a period of 3 weeks, reporting their daily levels of negative affect and stress. A Multivariate Actor Partner Interdependence Model was used to examine the extent to which each partner's RSA predicted their own and their partner's negative affect (NA) level, as well as NA stress-reactivity (i.e., the strength of the within-person stress-affect association). New mothers' tonic RSA predicted their own lower NA level and NA stress-reactivity; both their tonic RSA and RSA reactivity predicted their (male) partners' lower NA level; and finally, new fathers' tonic RSA and RSA reactivity predicted their (female) partners' lower NA stress-reactivity. These results suggest that RSA may serve as a personal and dyadic protective factor.

KEYWORDS

couples, ECG, negative affect, RSA, transition to parenthood

1 | INTRODUCTION

Most developed countries have seen a rapid decline in birth rates over the last three decades, to the extent that to date, most countries report near- or below-replacement fertility levels (Bongaarts, 2002; Kohler et al., 2002). Nevertheless, the vast majority of people still choose to become parents (Child Trends, 2002; Frejka, 2017; Miettinen et al., 2015). Indeed, for most people, parenthood is a central life goal (Kenrick et al., 2010), and a large majority of adults in Western countries continue to report a desire to have a child at some point in their lives (e.g., Martinez et al., 2006). Furthermore, motherhood or fatherhood are often associated with greater well-being, happiness, need satisfaction, life meaning, and life satisfaction (Ashton-James et al., 2013; Nelson-Coffey et al., 2019; Nelson et al., 2013; though see Evenson & Simon, 2005).

For many parents, however, the transition to parenthood (TTP) is far from painless. Infant care is often quite demanding both physiologically and emotionally (Denney et al., 2011;

Paulson & Bazemore, 2010; Saxbe et al., 2018) and parents need to adjust to changes in a variety of domains, including their social roles, daily routines, sleep habits, finances, and physical intimacy (Marshall & Tracy, 2009; Nomaguchi & Milkie, 2003). The birth of a child is often accompanied with a decline in parents' self-esteem (Bleidorn et al., 2016), relationship satisfaction (van Scheppingen et al., 2018), and spousal support (Simpson et al., 2003), as well as an increase in their psychosocial stress (Dunkel-Schetter et al., 2016; Reid & Taylor, 2015) and relational conflict (Doss et al., 2009). Furthermore, multiple large-scale meta-analyses indicate that approximately 20% of mothers and 10% of fathers suffer from clinical levels of postpartum depression (Gavin et al., 2005; O'Hara & McCabe, 2013; Paulson & Bazemore, 2010).

The variability in how people adjust to parenthood has led researchers to try to identify risk and resilience factors, which may be individual or dyadic (Doss & Rhoades, 2017; O'Hara & McCabe, 2013). For example, in a 22-year longitudinal study, mothers' and fathers' neuroticism predicted worse adaptation (i.e., lower life satisfaction), whereas fathers' openness to experience predicted better adaptation (Dyrdal & Lucas, 2013). In another large longitudinal study, intimate partners' support has been identified as a protective relational factor for mother's postpartum depression, and tended to exert greater favorable effect than support received from other sources (e.g., friends, family; Reid & Taylor, 2015; see also Dennis & Letourneau, 2007; Robertson et al., 2004). Relationship conflict and distress, in contrast, were found to be associated with higher levels of postpartum depression (Beck, 2001; Dennis & Ross, 2006).

In the current study, we adopt a biopsychosocial perspective for the understanding of factors associated with new parents' adaptation (Buultjens et al., 2013; Ross et al., 2004). Specifically, the main goal of the current study is to test whether new parents' parasympathetic activation—as reflected in the respiratory sinus arrhythmia (RSA)—serves as a protective factor for their emotional adjustment during the TTP. Furthermore, we seek to explore whether RSA functions as a *dyadic* protective factor—that is, whether its effect extends to their partners' emotional adjustment as well. This idea is consistent with previous work showing that the adjustment to parenthood tends to be a dyadic, rather than monadic, phenomenon, with a high degree of correspondence in how romantic partners adapt to parenthood (Dyrdal & Lucas, 2013).

1.1 | The role of RSA in social-emotional functioning

Heart rate variability—the magnitude of oscillations in time intervals between successive heartbeats—is a well-established biomarker of the parasympathetic nervous system's (PNS) control on the heart (Berntson et al., 1997). The PNS, one of the two branches of the autonomic nervous system, is responsible for maintaining a restorative state of physiological equilibrium and is particularly active during moments of rest, digestion, and social engagement. The PNS exerts its inhibitory effect on the heart through the myelinated vagus nerve. The vagal inhibitory influence on the heart vacillates along with the respiration cycle—it withdraws during inhalation and gets activated during exhalation. Therefore, RSA serves as a common index of cardiac vagal control, as it reflects the extent to which the myelinated vagal nerve modulates cardiac activity in the range of the respiratory frequency (Berntson et al., 1997).

The polyvagal theory (Porges, 2003, 2007) posits that RSA can index one's capacity for self-regulation in a complex social environment. The theory argues that the evolution of the autonomic nervous system facilitated the emergence of a new component—the myelinated vagus—which fosters a state of calmness necessary to engage in social interactions; it does so by attenuating the mobilizing stress response (e.g., fight or flight) associated with the sympathetic nervous system (SNS) and the hypothalamic-pituitary-adrenal (HPA) axis. Furthermore, the theory suggests that over the course of evolution, the brain-stem nuclei responsible for regulating the activity of the heart via the myelinated vagus nerve became intertwined with the nuclei that modulate facial muscles and sensory organs required to support social affiliative interactions. Therefore, RSA increases when one feels safe to engage socially with the environment; conversely, RSA decreases when one perceives threat in the environment, vagal control is suppressed, and the mobilizing fight-or-flight responses becomes more dominant. Notably, although the two branches of the autonomic system (i.e., the PNS and the SNS) often exhibit such a temporal pattern of reciprocal coordination (e.g., an increase in the SNS activation is accompanied with a decrease in the PNS activation), other functional dynamics, such as compensatory coordination (e.g., an increase in the PNS activation in complex social contexts which compensates for concurrent activation of the SNS) are also possible to optimize levels of arousal (Berntson et al., 1991; Gatzke-Kopp et al., 2020; Gatzke-Kopp & Ram, 2018).

Another prominent framework to the understanding of the association between RSA and self-regulation is the neurovisceral integration model (Thayer, 2009; Thayer & Lane, 2000, 2009). This model contends that the capacity to effectively organize goal-directed behaviors in accordance to situational demands is supported by the central autonomic network (CAN). The CAN is an internal neurological regulation system used to control and regulate visceromotor, neuroendocrine, and behavioral responses. One of the primary outlets of this system is mediated through the preganglionic parasympathetic neurons which influence the heart via the vagus nerve. Therefore, RSA is intimately linked to the output of the CAN, and thus, can be used as a peripheral index of one's capacity for self-regulation.

When considering the implications of RSA for social-emotional functioning, however, it is important to distinguish between *tonic* RSA (i.e., cardiac vagal control in resting wakefulness) and RSA reactivity (i.e., changes from baseline in cardiac vagal control in response to affective/social stimuli; Balzarotti et al., 2017; Butler et al., 2006; Muhtadie et al., 2015). Tonic RSA is conceptualized to index between-subject differences in vagal cardiac control, and therefore, in the capacity for regulation within dynamic situations. Indeed, a sizeable body of research indicates that tonic RSA is associated with better self-regulation and adaptive affiliative behaviors. For example, tonic RSA was found to be associated with more flexible attention and response to emotional stimuli (Fujimura & Okanoya, 2012; Holzman & Bridgett, 2017; Ode et al., 2010; Park et al., 2013; Ruiz-Padial et al., 2003), and with employment of adaptive emotional regulatory strategies (Aldao et al., 2016; Fabes & Eisenberg, 1997; Geisler et al., 2013; Volokhov & Demaree, 2010). Consistent with these findings, tonic RSA tends to be lower among people suffering from alexithymia (Lischke, Pahnke, et al., 2018) as well as various affective and anxiety disorders (Alvares et al., 2013; Chalmers et al., 2014). Additionally, tonic RSA is associated with a host of adaptive social indices including more accurate social cognition (Côté et al., 2011; Lischke et al., 2017; Quintana et al., 2012), social connection (Hopp et al., 2013; Kok et al., 2013), cooperation (Beffara et al., 2016), empathy (Lischke, Pahnke, et al., 2018) , support (Maunder et al., 2012), and lower levels of social stress (Lischke, Jaksteit, et al., 2018).

By contrast, RSA reactivity is believed to reflect one's self-regulatory efforts in response to situational demands. According to the polyvagal theory (Porges, 2003, 2007), when facing stress or challenge, inhibitory vagal control on the heart should decrease (resulting in lower RSA reactivity) to allow the metabolic requirements essential for mobilization responses (e.g., fight/flight behaviors). However, the theory contents, that when a person is involved in safe social situations, vagal inhibitory cardiac control should be maintained or even increased (resulting in higher RSA reactivity) to allow affiliative and safe social interactions (Porges, 2003, 2007). It is, therefore, imperative to consider the affective/social context in which RSA reactivity is measured.

Consistent with this idea, several studies have found that greater cardiac vagal withdrawal in response to *situational stress or challenge* (as reflected in a decrease in RSA from baseline to task) is associated with adaptive social-emotional functioning. For example, vagal withdrawal was found to be associated with lower levels of social loneliness, greater accuracy in social-emotional perception, and context-appropriate emotional responses in social situations (Muhtadie et al., 2015). Similarly, vagal withdrawal has been tied to higher positive affect levels (Heponiemi et al., 2006), and to lower negative affect reactivity to daily negative interactions (Diamond et al., 2011; though see others [e.g., Gouin et al., 2014] for results showing that vagal withdrawal is associated with greater distress). In contrast, in affiliative contexts, higher RSA reactivity (reflected in an increase in RSA from baseline to task) was found to be associated with better social-emotional functioning. For example, RSA increase was found to be associated with stronger feelings of compassion to the suffering of others as well as greater behavioral expression of compassion (Stellar et al., 2015). RSA reactivity was also found to be positively associated with better emotional regulation during interpersonal interaction (Butler et al., 2006). Additionally, among depressed individuals, an increase in RSA was observed in interactions with significant others versus when alone (Schwerdtfeger & Friedrich-Mai, 2009).

1.2 | The role of RSA in romantic relationships

For many adults, the romantic relationship is one of the most significant affiliative bonds in their lives (Kiecolt-Glaser & Wilson, 2017; Robles et al., 2014; Shaver & Mikulincer, 2012), one which has a paramount role in emotional experience and regulation (Sbarra & Coan, 2017; Sbarra & Hazan, 2008). For this reason, a growing number of studies have explored the association between RSA and partners' social-emotional functioning.

Studies exploring tonic RSA have consistently documented its association with favorable relational outcomes. For example, tonic RSA has been tied to one's own as well as one's partner's self-reported relationship quality (Smith et al., 2011). Similarly, romantic partners with higher tonic RSA reported experiencing daily relational interactions of higher quality; furthermore, tonic RSA attenuated the association between negative affect and negative relational interaction, and strengthened the association between positive affect and positive relational interactions (Diamond et al., 2011). RSA was also found to play a critical role in relational conflict; specifically, within this often-challenging context, RSA buffered the association between rumination and conflict intensity (Caldwell et al., 2019), between expressive suppression and negative affect (Geisler & Schröder-Abé, 2015), and between rejection sensitivity and hostility (Gyurak & Ayduk, 2008). Similarly, tonic RSA buffered the association between negative responses to one's partner's stress (e.g., criticism, withdrawal) and the partner's subsequent depressive symptoms (Switzer et al., 2018).

The literature on RSA reactivity is much more limited, yet, is commensurate with the ideas put forward by the polyvagal theory. For example, higher RSA reactivity during stress-inducing tasks (i.e., an increase in RSA from baseline to task) was found to strengthen the association between daily negative affect and poor quality of relational interactions (Diamond et al., 2011; see also Gouin et al., 2018). In contrast, in a recent observational study of supportive (affiliative) dyadic interactions, subjects with greater RSA reactivity provided more emotional support to their partners and were perceived as more sensitive (Borelli et al., 2019).

1.3 | Present study

The main goal of the current study is to test new parents' RSA as a dyadic protective factor. To the best of our knowledge, no study to date has examined whether new parents' RSA is associated with their own or their partner's emotional adjustment during the TTP. To test this, we used data collected from new parents who participated in a lab session during which their RSA was monitored at baseline (used to quantify tonic RSA) and during various affiliative tasks (used to quantify RSA reactivity). Couples then completed diaries tapping their daily experiences.

We focused on two daily affective outcomes—negative affect (NA) levels and NA stress-reactivity. NA *level* is a dispositional mood dimension capturing people's tendency to experience a variety of aversive moods such as tension, worry, resentment, and anger (Watson & Clark, 1984). It is conceptualized as one core component of (diminished) subjective well-being (Busseri, 2018; Diener et al., 1999). Furthermore, several models posit that chronic levels of negative affect are a defining feature of mood and anxiety disorders (Brown & Barlow, 2009; Clark & Watson, 1991; Hofmann et al., 2012). In the context of the TTP, people's high NA levels are predictive of their own and their partners' postpartum distress and depression (Brenning et al., 2019; Le et al., 2017; Morse et al., 2000) and of maladaptive parenting behaviors (Rueger et al., 2011). High levels of parental NA are also associated with poor infant development (Aktar & Bögels, 2017; Aktar et al., 2018). Notably, the tendency to experience high levels of NA is associated with both tonic RSA and RSA reactivity (Caldwell et al., 2019; Diamond et al., 2011).

NA *stress-reactivity* is defined as one's tendency to react strongly to stressors—that is, to demonstrate a strong positive within-person association between situational stress and situational NA (Bolger & Zuckerman, 1995). Such reactivity is conceptualized as a vulnerability disposition that represents poor stress-coping processes (e.g., coping choice and effectiveness) and difficulties in NA downregulation (Bolger & Zuckerman, 1995). Consistent with this idea, NA stress-reactivity is associated with reduced well-being (Stanton et al., 2019) and mental health (Charles et al., 2013), and with a myriad of unfavorable health outcomes, including impaired sleep (Ong et al., 2013), elevated inflammation (Sin et al., 2015), and mortality (Stanton et al., 2019).

To the best of our knowledge, NA stress-reactivity has yet to be assessed within the TTP; nevertheless, there is a breadth of studies documenting the formidable effect of stress on new parents (Brummelte & Galea, 2010; Da Costa et al., 2000; Page & Wilhelm, 2007; Reid & Taylor, 2015). In line with the proposed role of RSA in regulatory affective processes, a recent 10-year longitudinal study showed that tonic RSA buffers the prospective association between NA stress-reactivity and marital distress (Ong et al., 2019).

To summarize, the present work adopts a biopsychosocial perspective to better understand new parents' adaptation to the challenges of the TTP (Buultjens et al., 2013; Ross et al., 2004). In particular, we sought to examine the association between new parents' RSA and their—as well as their partners'—NA levels and NA stress-reactivity. The following hypotheses were tested:

Hypothesis 1 *Actor and Partner effects of Tonic RSA. Based on findings showing that tonic RSA (i.e., RSA assessed during baseline) is associated with better affect regulation (Appelhans & Luecken, 2006), and that it is linked with both personal and dyadic favorable outcomes (Smith et al., 2011), we predicted that tonic RSA would be negatively associated with one's own (actor effect) as well as one's partner's (partner effect) daily NA level and NA stress-reactivity.*

Hypothesis 2 *Actor and Partner effects of RSA reactivity. Based on findings showing that RSA reactivity in affiliative interactions (i.e., an increase in RSA from baseline to task) is positively associated with salubrious personal and relational outcomes (Borelli et al., 2019; Butler et al., 2006), we predicted that an increase in RSA during affiliative dyadic interactions (i.e., positive RSA reactivity score) would be negatively associated with one's own (actor effect) as well as one's partner's (partner effect) daily NA level and NA stress-reactivity.*

2 | METHOD

2.1 | Participants

The current sample of 109 heterosexual couples was recruited as part of a larger longitudinal project, focusing on dyadic processes in the TTP (see Sened et al., 2020). Adult couples (age > 18) were recruited from the community through social media, forums, flyers, and word of mouth. To be included, they needed to be expecting a single first child. Seven couples dropped out of the study after giving birth, and two dropped out during the diary period. The mean age of the 100 remaining couples was 30.3 for men ($SD = 4.15$, $Range = 23–42$) and 28.6 for women ($SD = 4.32$, $Range = 19–46$). Mean relationship length was 4.86 years ($SD = 2.96$, $Range = 1.33–12.66$).

2.2 | Procedure

During the third trimester of the pregnancy, couples completed a battery of background questionnaires during a home visit. At 15 weeks postpartum, couples took part in a lab session. They were instructed to refrain from smoking cigarettes or consuming alcoholic and caffeinated beverages for at least 2 hr before arriving at the lab. Upon arrival, partners were separated into two rooms, and were asked to sit quietly and refrain from gross movements for 6 min, during which their baseline physiological arousal was recorded. Following this baseline assessment, partners were led into a dyadic interaction room and participated in four 6-min dyadic interactions. In the first two interactions, each partner in turn was asked to raise a personal problem, unrelated to the relationship; this dyadic task was designed to elicit supportive behaviors in response to the disclosure of personal difficulties or negative experiences (Pasch & Bradbury, 1998). In the last two interactions, each partner in turn was asked to disclose a positive personal experience; this dyadic task was designed to elicit supportive behaviors in response to the disclosure of personal successes and positive experiences (Gable et al., 2006). Following each of these interactions, participants were asked to complete a brief (three-item) measure of perceived partner responsiveness (Maisel & Gable, 2009), on a scale ranging from 1 (“not at all”) to 5 (“very highly”; Cronbach's $\alpha = 0.89$). Participants’ average rating was 4.42 ($SD = 0.66$), indicating that, consistent with previous research (Gable et al., 2006; Kordahji et al., 2015; Pasch & Bradbury, 1998; Zahavi et al., 2018), these tasks were successful in eliciting dyadic affiliative behaviors.

Following the lab visit, couples were asked to complete an online daily diary questionnaire for 21 days. Each evening, a unique link was sent to each partner's personal email, with instructions to complete the diary approximately 1 hr before going to sleep. On average, couples completed 20.3 ($SD = 1.25$) diary entries, out of 21.[1] Notably, the number of completed daily entries was not associated with any of the variables examined in this study, suggesting the diary data were missing at random.

[1]For technical reasons, for 17 participants the diary was not ended on time (after 21 days), and they therefore, provided additional 1–2 daily entries. These additional entries were included in the computation of the diary measures (i.e., NA level and NA stress-reactivity). However, removing these entries did not change the pattern of results reported in the article.

2.3 | Measures

2.3.1 | RSA estimation

To continuously record partners’ECG signals, three electrodes were positioned in a modified lead II placement (i.e., two across the chest, below the ribs, and one near the collarbone). Heart rate was sampled at 1,000 Hz with the BioLab Acquisition Software and a BioNex 8-slot Chassis. Data from these recordings were processed offline using the MindWare HRV software. ECG data were visually inspected for artifacts, and missing or misidentified heartbeats were manually deleted or inserted as appropriate. When no R wave could be identified in the signal we estimated its location as the middle of the two surrounding R waves. The processed data were then used to estimate RSA separately for each task. In accordance with the recommendations provided by Berntson and colleagues (1997), each subject's IBI series was interpolated to obtain equally spaced HR time series at 33 Hz, and then, de-trended to minimalize non-stationarity. The residualized data were tapered with a Hanning window and submitted to a Fast Fourier Transform to derive the spectral distribution. RSA was quantified as the integral power within adults’ respiratory frequency band (0.12 to 0.40 Hz).[2] Tonic RSA was operationalized as partners’ RSA during the baseline assessment. RSA reactivity was operationalized by subtracting tonic RSA from the RSA assessed during each of the four dyadic interactions. Due to the strong associations among the four difference scores (r’s ≥ 0.87), RSA reactivity was computed as the average of these scores (Cronbach's $\alpha = 0.95$; Muhtadie et al., 2015).

2.3.2 | Diary measures

Partners’ NA was assessed using an adapted and shortened daily diary version (Cranford et al., 2006) of Lorr and McNair's (1971) Profile of Mood States. Specifically, NA level was operationalized as the average score of the items indexing anger (annoyed, resentful, and anger), anxiety (on edge, uneasy, and anxious), and sadness (hopeless, discouraged, and sad). Using a 0–4 Likert scale (ranging from “not at all” to “extremely”), participants were asked to indicate the extent to which they are experiencing each of these states at the current moment. The between-persons and within-person reliabilities were computed using procedures outlined

[2]The question of whether respiration rate should be taken into account when measuring RSA has been debated (e.g., Denver et al., 2007; Grossman & Taylor, 2007). In the current study, we used respiration belts to monitor partners’ respiration rate. Unfortunately, for technical reasons, the data obtained from these belts were not reliable, and thus, could not be used to test whether statically controlling for respiration alters the obtained results.

TABLE 1 Means, *SD*s, and correlations of the study's variables

	Mean (*SD*)	Zero order correlations 2	3	4	5	6	7	8
Mothers' variables								
1. Tonic RSA	6.38 (1.02)	−0.655***	−0.230*	−0.182†	−0.189†	0.065	−0.265**	−0.161
2. RSA reactivity	0.51 (0.70)		0.066	0.099	0.144	−0.056	0.021	0.134
3. NA level	0.35 (0.30)			0.535***	−0.009	−0.120	0.371***	0.135
4. NA reactivity	0.30 (0.13)				−0.231*	−0.214*	0.147	0.107
Fathers' variables								
5. Tonic RSA	6.29 (0.81)					−0.294**	−0.009	−0.046
6. RSA reactivity	0.30 (0.60)						0.037	0.026
7. NA level	0.34 (0.38)							0.321***
8. NA reactivity	0.29 (0.12)							

†$p < .10$; *$p < .05$; **$p < .01$; ***$p < .001$.

in Cranford et al. (2006). Respectively, the between-person and within-person reliabilities were 0.86 and 0.82 for men and 0.76 and 0.86 for women. To assess daily stress, participants responded to five items inquiring about stressful events experienced outside their relationship (e.g., chores, physical health, and baby care). Items were rated on a 0–4 Likert scale, and their average was used to index the level of daily stressors. Following procedures used in previous studies (Charles et al., 2013; Ong et al., 2019; Piazza et al., 2013; Sin et al., 2015), *NA stress-reactivity* was computed for each participant using a two-level multilevel model in which participants' daily NA was regressed on their reported daily stress. In this model, the fixed effect, representing the sample's average association between stress and NA, was positive and significant (*Est.* = 2.94, *SE* = 0.02, $p < .001$). To compute participants' individualized NA stress-reactivity score, we obtained the empirical Bayes level-2 random estimates, representing the extent to which participants deviated from the average reactivity effect (Raudenbush & Bryk, 2002).

2.3.3 | Missing data

The diary measures were complete enough so that no participant had missing NA level or reactivity indices. With the ECG signals, we excluded data in interactions in which more than 3% of the R waves were missing or in which artifacts needed to be manually estimated. This resulted in a loss of RSA data (both tonic RSA and RSA reactivity) from eight participants. Two additional participants had missing RSA reactivity data.

3 | RESULTS

The descriptive statistics of the study's variables are presented in Table 1. Notably, mothers' and fathers' RSA reactivity scores were positive, indicating that on average, participants showed an increase in their RSA during the affiliative interactions versus the baseline assessment ($t[95] = 7.06$, $p < .001$ and $t[93] = 4.88$, $p < .001$, for mothers and fathers, respectively).

Our data were hierarchically nested within dyads, and thus, containednonindependence. Therefore, to test the association between tonic RSA and RSA reactivity with the daily affective outcomes (Hypotheses 1 and 2), we estimated an Actor– Partner Interdependence Model (APIM; Kenny et al., 2006). In it, both one's own RSA indices (i.e., Actor effects) and one's partner's RSA indices (i.e., Partner effects) were used as predictors. In addition, the covariances between partners' predictors as well as between the outcomes' residual scores are modeled. Finally, because the two outcomes—NA level and NA stress-reactivity—were positively correlated ($r = 0.41$), we estimated one multivariate APIM model in which the two different outcomes' residuals were allowed to correlate. The full model is illustrated in Figure 1. The model was estimated using the "*lavaan*" package (Rosseel, 2012) in the R software platform (R Core Team, 2016).[3] The full

[3]We opted to use the two-step approach detailed above (extracting individualized NA stress-reactivity slopes from a multilevel model, and using these as a between-subject outcome) in keeping with previous work in the field (see Charles et al., 2013; Ong et al., 2019; Piazza et al., 2013; Sin et al., 2015). Doing so also allowed us to treat stress-reactivity as a latent variable, and thus, compute standardized effects within an *SEM* framework. We should note that previous work using this approach has treated stress-reactivity as a predictor, whereas we use it as an outcome. To ensure that this novel approach does not bias the results, we also applied an alternative analytic strategy—namely, estimating a multilevel model in which partners' RSA indices serve as level-2 predictors of participants' daily NA levels (intercepts) and NA stress-reactivity (stress slopes). This (more traditional) strategy yielded a very similar pattern of results to the ones reported here. (For full results, please see https://osf.io/7wj3p/).

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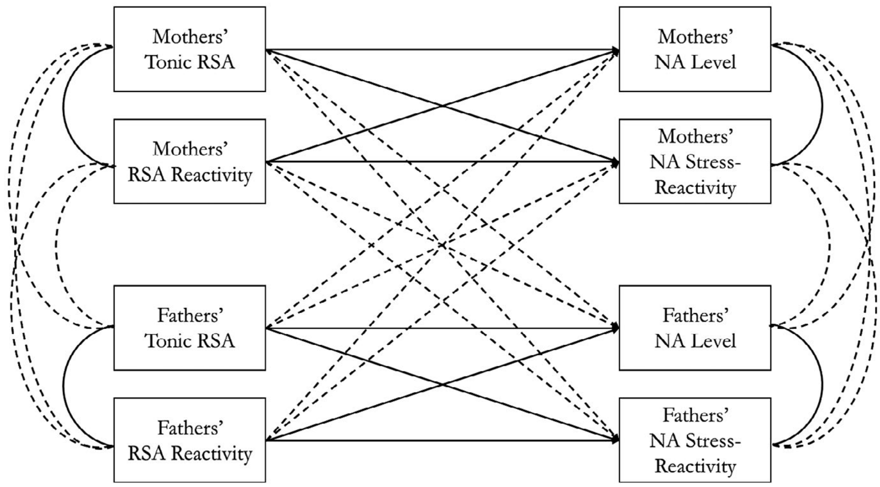

FIGURE 1 The estimated multivariate actor partner interdependence model. Solid lines represent actor effects and covariations between actor's variables. Dashed lines represent partner effects and covariations between partners' variables

TABLE 2 Standardized effects from the multivariate actor partner interdependence model

	Mothers' outcomes		Fathers' outcomes	
	NA level	NA stress-reactivity	NA level	NA stress-reactivity
Mothers' indices				
Tonic RSA	−0.336*	−0.296*	−0.479***	−0.155
RSA reactivity	−0.123	−0.055	−0.270*	0.032
Fathers' indices				
Tonic RSA	−0.104	−0.368***	−0.058	−0.075
RSA reactivity	−0.135	−0.301**	0.037	0.016

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

information maximum likelihood estimation was used to handle missing data (Allison, 2003).

The results of the model are presented in Table 2. As the Table shows, new mothers' NA level and stress-reactivity were negatively associated with their tonic RSA. In addition, new mothers' NA stress-reactivity was negatively associated with their (male) partner's tonic RSA and RSA reactivity. New fathers' NA level was negatively associated with their (female) partner's tonic RSA and RSA reactivity; in contrast, new fathers' NA stress-reactivity was not associated with their own or their partners' RSA indices.

4 | DISCUSSION

The central aim of the current study was to test whether new parents' RSA—an established physiological marker of parasympathetic system functioning—is associated with emotional adjustment to the transition to parenthood. For many people, parenthood is considered a highly valued life goal (Kenrick et al., 2010) and associated with happiness and satisfaction (Nelson et al., 2013). Nevertheless, new mothers and fathers often find it emotionally challenging to adjust to this major life transition. Drawing upon ideas from the polyvagal theory and the neurovisceral integration model, which posit that RSA can serve as an indicator of one's capacity for social-emotional regulation (Porges, 2003), we proposed (and found some evidence supporting the idea) that new parents' tonic RSA and RSA reactivity would be associated with better emotional adjustment—that is, with reduced NA levels and reduced NA stress-reactivity. The findings also corroborate biopsychosocial models of adjustment to parenthood (Buultjens et al., 2013), in showing that RSA can be considered as a dyadic protective factor, with both intrapersonal (actor) and interpersonal (partner) effects of RSA emerging in our data.

In partial support of our prediction that tonic RSA would be associated with the actor's better emotional adjustment, mothers' tonic RSA was indeed associated with their own lower NA levels and NA stress-reactivity. These findings can be interpreted in line with previous studies showing that tonic RSA is associated with adaptive emotional processes. For example, individuals with high tonic RSA differentiate better between negative and neutral or positive emotional stimuli (Park et al., 2012; Ruiz-Padial et al., 2003), and demonstrate less attention bias to negative emotional stimuli (Miskovic & Schmidt, 2010; for review see Park & Thayer, 2014), which may ultimately result in lower levels of NA. High tonic RSA is also associated with the employment of more adaptive emotion-regulation strategies (e.g., reappraisal; Geisler et al., 2010), which may help partners to regulate their emotional reactivity to stress. It is thus possible that such advantageous emotional processes help new mothers to traverse the emotional challenges associated with parenting. After all, caring for an infant can elicit feelings of joy and delight, but also ones of anxiety and anger (Nelson et al., 2014). The ability to differentiate between these experiences and to be less biased toward attending to negative feelings may improve new mothers' psychological well-being. It is thus important, in future studies, to test such affective processes as potential daily mechanisms for tonic RSA effects.

Another putative mechanism that may account for the salutary effects of mothers' tonic RSA is sleep quality. New mothers are susceptible to developing sleep disturbances (e.g., insomnia symptoms, poor sleep quality, and fatigue; Gay et al., 2004), which are intimately linked to heightened negative affect and depressive symptoms (Okun, 2016). Notably, a recent study illustrated that new mothers' tonic RSA buffered the deleterious effects that stress exerted on sleep quality, resulting in lower sleep reactivity to stress and lower depressive symptoms (da Estrela et al., 2020). Future studies should test whether sleep quality plays a central role in the association between mothers' tonic RSA and their affective adjustment to the TTP.

Though, contrary to our prediction, new fathers' tonic RSA was not associated with *their* emotional adjustment, it was predictive of their female partners' lower NA stress-reactivity; a similar partner effect was found with new mothers' tonic RSA, which predicted their male partners' lower NA levels. In other words, in partial support of our predictions, the beneficial effects of tonic RSA extended to one's partner as well.

One possible daily process underlying these partner effects may be *emotional transmission* (Larson & Almeida, 1999)—the process through which one intimate partner's emotions at a particular time point tend to predict the other's at a subsequent time point, creating a dynamic network of dyadic emotional feedback loops (Bar-Kalifa & Sened, 2019; Butler & Randall, 2013; Randall & Schoebi, 2015). Thus, it may be that because people with high tonic RSA are in a better position to regulate their own distress (Balzarotti et al., 2017), they are less likely to transmit NA to their partners, culminating in lower NA levels (as was found for the male partners of high tonic RSA women). Additionally, tonic RSA is associated with more constructive interpersonal behaviors. When facing stressful interpersonal situations (e.g., anger-provoking conflicts), those high in tonic RSA are likely to adopt more adaptive interpersonal behaviors, as has been found both within and outside of intimate relationships (e.g., Diamond et al., 2011; Dunn et al., 2012; Geisler & Schröder-Abé, 2015; Gyurak & Ayduk, 2008; León et al., 2009; Souza et al., 2007). This suggests that partners of those high in tonic RSA may enjoy a more supportive relational atmosphere, and thus, may be less taxed and better able to regulate their own distress, as may be reflected in lower NA stress-reactivity (as was found for the female partners of high tonic RSA men).

We also tested whether RSA reactivity, and more specifically—the change in partners' RSA from baseline to affiliative interactions—can predict new parents' emotional adjustment. The polyvagal theory argues that the myelinated vagus nerve supports the physiological state of calmness required for engaging in affiliative interpersonal interactions (Porges, 2007). Premised on this idea, we expected that an increase in new parents' RSA during dyadic affiliative tasks would be associated with both actors' and partners' emotional adjustment. Contrary to our actor-effect predictions, no actor effect emerged for either the mothers' or fathers' RSA reactivity. In contrast, and in partial support of our partner-effect predictions, two significant partner effects emerged—increases in new mothers' RSA levels (i.e., positive reactivity scores) predicted their male partners' lower NA level, and increases in new fathers' RSA levels predicted their female partners' lower NA stress-reactivity. These findings can be understood as reflecting the beneficial effects of partners' regulatory efforts to sustain positive engagement while interacting with each other. Indeed, in a recent study in which participants were asked to disclose personal difficulties and discuss them with their romantic partners, listeners who demonstrated increases in RSA provided greater levels of emotional support (Borelli et al., 2019). Notably, partners' emotional support is effective in reducing daily levels of NA (Bar-Kalifa & Rafaeli, 2015).

Relatedly, the extant literature has found RSA reactivity to be associated with compassion and with motivation to soothe distressed others. For example, in Stellar et al.'s study (2015) participants who evidenced increases in RSA upon observing another person's suffering, reported greater levels of compassion and enacted more compassion-related behaviors. Thus, it is possible that new parents' RSA increase signifies their capacity to be compassionate and supportive toward their partner's hardship during the challenging TTP period; such dyadic support is recognized as an important protective factor against new parents' distress (O'Hara & McCabe, 2013; Reid & Taylor, 2015), and may partially account for the partner RSA reactivity effects found in our study (i.e., fathers' lower NA levels and mothers' lower NA stress-reactivity).

We now turn to discussing the gender differences that emerged in the current study. Fathers' emotional adjustment was not predicted by their tonic RSA or RSA reactivity, but their NA level was predicted by their (female) partner's tonic RSA and RSA reactivity. This "partner-only" pattern of results (Kenny & Ledermann, 2010) for men can be interpreted in line with the different roles that men and women tend to adopt in heterosexual romantic relationships. One typical difference documented is a gender imbalance in "emotional work," with women attending more to emotional needs, providing more emotional support, and devoting greater effort to resolving conflicts and maintaining closeness (Denton & Burleson, 2007; Strazdins & Broom, 2004; though see Curran et al., 2015). Furthermore, women's emotional work often exerts a greater impact on their and their (male) partners' relationship satisfaction (Horne & Johnson, 2019). This unequal division may explain why it is that (female) partners' regulatory capacity may be more consequential to their male partners' emotional adjustment than the men's own capacity.

For women, however, both actor and partner effects emerged. In other words, both their own and their partner's regulatory capacity were critical in predicting their daily emotional adjustment. What might explain the somewhat surprising finding that men's regulatory capacity does matter? One explanation may be that even though women's regulatory capacity is more consequential to couples' well-being in general, the unique challenges of the TTP bring men's regulatory capacity to the fore. Though modern fathers take on considerably greater childcare responsibilities than fathers in earlier decades (Parker & Wang, 2013), mothers continue to shoulder the lion's share of infant care (Yavorsky et al., 2015). Therefore, it may be that during this period, when new mothers' regulatory capacity is stretched, their partners' supportive and regulatory role becomes more prominent, and their abilities for managing emotions and maintaining the affiliative bond become predictive of their (female) partner's adjustment.

4.1 | Limitations and future directions

This study provides the first evidence for the idea that new parents' RSA is associated with favorable daily emotional adjustment. Nevertheless, it is silent regarding the mechanisms responsible for this association. If we were to adopt the framework provided by the process model of emotion regulation (Gross, 2014), we may find that new parents' RSA is implicated in the regulation of any of the sequential steps of emotion generation. Better emotional adjustment of those new parents with higher RSA can be explained, for example, by their tendency to circumvent stressful daily events (situation selection and modification; Hamilton & Alloy, 2017), to pay less attention to negative experiences (attentional deployment; Park & Thayer, 2014), to interpret demanding tasks such as infant care more favorably (cognitive change; Geisler et al., 2010), and to accept and seek more support when dealing with negative emotions (response modulation; Geisler et al., 2013). These are, of course, speculations—and each of these suggested mechanisms warrants future exploration.

The current study used daily NA level and stress-reactivity as the key outcomes in our analyses. These constructs are consequential in and of themselves. For example, high NA is considered a fundamental aspect of poor subjective well-being (Diener et al., 1999) and NA stress-reactivity has been found to be implicated in daily markers of inflammation (Sin et al., 2015). However, it is imperative to examine whether new parents' tonic RSA and RSA reactivity can be used to predict more distal indices of new parents' relational, mental, and physical well-being (Ong et al., 2019; Sin et al., 2015; Stanton et al., 2019), as well as of their parental functioning (Musser et al., 2012). Notably, such examination would probably require recruiting larger samples of TTP couples than the one utilized in the current study.

It should be noted that we assessed new parents' RSA postnatally. RSA indices are considered to represent stable trait-like biological markers of parasympathetic system cardiac control (Bertsch et al., 2012; Bornstein & Suess, 2000). Nevertheless, it may be that the RSA measurements in the current study reflect, at least to some degree, changes in new parents' tonic RSA and RSA reactivity that have already transpired since the birth of the child. To provide a more stringent test of RSA as a dyadic prospective protective factor in the transition to parenthood, future studies may wish to monitor parents' prenatal (or even prepregnancy) RSA.

When individuals experience social safety, increased vagal control on the heart is conceptualized to be an adaptive response that permits affiliative interaction (Borelli et al., 2019; Porges, 2007). Based on this idea, we measured RSA reactivity within various supportive dyadic interactions, and indeed found that on average, partners demonstrated an increase in RSA from baseline to these affiliative dyadic tasks. However, our study says little about the role of RSA in interactions marked by stress or conflict. According to the polyvagal theory, the myelinated vagus nerve supports flexible reactions to dynamic changes in one's social environment. It is reasonable to predict that when individuals face stressors or experience relational distress, withdrawal from cardiac vagal control (i.e., a decrease in RSA) would constitute an adaptive response (Muhtadie et al., 2015; Shahrestani et al., 2015). However, even this may represent an oversimplified notion of what constitutes "optimal" RSA change. For example, Beauchaine (2015) has recently pointed out that either low or excessive RSA reactivity may indicate poor regulatory capacity. Thus, to go beyond what was found in the current study, future studies could examine more complex (e.g., nonlinear) patterns of associations between RSA reactivity and new parents' adjustment; they could also monitor RSA during a more diverse set of interactions varying in their degree of interpersonal safeness versus stress (e.g., capitalization, support, dyadic stress, and conflict). Indeed, a substantial amount of variance (~40%) in RSA may be explained by situational effects and by the person-by-situation interplay

(Bertsch et al., 2012). In short, the examination of RSA reactivity in different situations could provide a more comprehensive and nuanced picture of the role played by phasic RSA in partners' emotional adjustment.

Finally, the current study focuses only on an index of PNS cardiac control (i.e., RSA). However, the sympathetic and the parasympathetic branches of the nervous system could be involved in various coordinated dynamic patterns, such as reciprocal activation, co-activation, and co-inhibition (Alkon et al., 2003; Berntson et al., 1991). Furthermore, a recent study examining the temporal association of the two branches among kindergarten-aged children demonstrated a meaningful between-subject variability in PNS-SNS coordination as well as variability in this coordination as a function of affective context (Gatzke-Kopp et al., 2020). Thus, to go beyond our results, future studies could collect PNS and SNS indices simultaneously. This will allow elucidating which type of interplay between the two branches best supports dyadic adaptation to the TTP.

4.2 | Summary and clinical implications

To the best of our knowledge, the present study is the first to test the longitudinal dyadic effects of couples' RSA, both in general and in the specific context of the TTP. It is also novel in combining lab-based dyadic psychophysiology with the use of daily diaries; the latter allowed us to monitor new parents' emotional adjustment, close in time to their experience, thus, strengthening the ecological validity of the study's results.

Our findings are consistent with several models addressing the adjustment to parenthood as a dyadic biopsychosocial phenomenon (Buultjens et al., 2013; Dyrdal & Lucas, 2013; Ross et al., 2004). As such, they highlight the interplay between biological (i.e., RSA), psychological (emotional adjustment), and social factors (e.g., relational effects) in the adjustment to parenthood of new mothers and fathers. Specifically, we found support for the idea that both partners' RSA may function as *dyadic* protective factors in this often-challenging period.

The obtained results should surely be replicated, examined in additional settings and populations, and probed for the underlying processes, before any solid clinical recommendations are drawn. Nonetheless, we believe that our findings are at least suggestive of the idea that RSA may help identify expectant or new parents who are at risk for emotional maladjustment. Due to their cost-effectiveness and high validity, self-report questionnaires are the most common method for evaluating new-parents distress (Langan & Goodbred, 2016; Latendresse et al., 2015; Sit & Wisner, 2009; Committee on Obstetric Practice, 2015). However, the widely available wearable biosensors may make ambulatory assessment of RSA (Colombo et al., 2019; Hallgren et al., 2017; Timmons et al., 2017) relatively easy to obtain and utilize as a complement for existing methods of assessment.

Several studies have provided promising evidence that biofeedback (Bornemann et al., 2016) and meditation (Kok et al., 2013) can be used to upregulate RSA (see also Bradford & Bar-Kalifa, 2020). Interestingly, a recent study demonstrated that even traditional psychotherapy, not specifically tailored to alter clients' RSA, can result in an increase in RSA over the course of therapy (Blanck et al., 2019). If the results of future studies corroborate the findings reported here, such interventions, aimed at fortifying couples' dyadic resilience, may be a fruitful avenue for prevention or intervention efforts for couples undergoing the exciting, but often stressogenic, transition into parenthood.

AUTHOR CONTRIBUTION

Eran Bar-Kalifa: Conceptualization; Data curation; Formal analysis; Writing-original draft. **Michal Abba Daleski:** Data curation. **Rony Pshedetzky:** Data curation; Project administration. **Marci Gleason:** Conceptualization; Funding acquisition. **Rafaeli Eshkol :** Conceptualization; Funding acquisition; Writing-review & editing.

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