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Family alliance and infants' vagal tone: The mediating role of infants' reactions to unadjusted parental behaviors

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Abstract

We investigated the influence of family alliance on infants' vagal tone. Physiological studies have shown that the quality of mother–infant interactions can influence infants' vagal tone, which is an important indicator of emotion regulation. Although research has shown that family-level relationships have a unique impact on child development, little is known about the association between the quality of mother–father–infant interactions and infants' physiological regulation during a family interaction task. We hypothesized that infants in families with a greater family alliance, that is, degree of coordination reached by parents when completing a task, will have higher vagal tone than will infants in families with a lower family alliance. We also hypothesized that this association would be mediated by the amount of intrusive and withdrawn parental behaviors and by the impact of these behaviors on the infant during mother–father–infant interactions. This study included 82 parents with their 3-month-old infants. Results showed that family alliance was associated with infants' vagal tone during triadic interactions and that the impact of intrusive/withdrawn parental behaviors on the interaction partially mediated this association.

KEYWORDS
family alliance, infant, mother–father–infant interactions, parental behavior, physiological regulation

1 | INTRODUCTION

Relationships within the family have been shown to be a strong predictor of children's socioemotional functioning. This has been shown at the level of dyadic relationships, in mother–infant relationships (e.g., Brumariu, 2015; Calkins & Hill, 2007; Field et al., 2007), in father–infant relationships (Anderson et al., 2013; Braungart-Rieker et al., 2014; Bureau et al., 2020), and at the triadic level of mother–father–infant relationships (Favez et al., 2006, 2012; Kolak & Vernon Feagans, 2008). At the triadic level, the way that parents coordinate and support each other in their relationship with the child influences the child's psychological adjustment (Teubert & Pinquart, 2010) and socioemotional functioning beyond individual parental behaviors (Belsky et al., 1996; Caldera & Lindsey, 2006; Karreman et al., 2008). To obtain a better understanding of the processes underlying the association between the quality of triadic interactions and infant's socioemotional outcomes, we investigated the influence of mother–father–infant interactions on infants' vagal tone, an indicator of physiological emotion regulation, as well as the interactional process that might explain this influence.

Emotion regulation is one of the key processes in individual functioning, and poor abilities to regulate emotion might explain psychological difficulties (Cole & Deater-Deckard, 2009; Cole & Hall, 2008; Halligan et al., 2013). Emotion regulation is defined as "the process responsible for monitoring, evaluating, and modifying emotional reactions, especially their intensity and temporal features, in order to accomplish one's goal" (Thompson, 1994, p. 27–28). At birth, infants have immature emotion regulation abilities. Although they have an innate repertoire of regulatory behaviors, such as falling asleep, closing their eyes, turning their head away or nonnutritive sucking (Calkins et al., 2016; Kopp, 1989) they mostly need the adult to help them regulate. Emotion displays from infants are used as messages sent to the adults who, in response, adapt their behavior directed to the child so that the environment and the internal state of the infant is modified (Cole et al., 2004; Field, 1994; Tronick, 1989). Through the repetition of this process, infants learn to understand their internal states and how to regulate emotions. After an initial stage during which emotions are entirely regulated by caregivers, a process of coregulation takes place as infants grow up. Finally, infants become capable of self-regulation (Sameroff, 2004). Thus, the development of emotion regulation in infants is an interpersonal process. As a consequence, the quality of the early relational context, especially the interactions with caregivers, has a major influence on the development of emotion regulation abilities (Cole et al., 2004; Morris et al., 2007).

The influence of the quality of parent–infant interactions on the ability of the infant to regulate emotion has been studied widely in mother–infant interactions (e.g., Brumariu, 2015; Calkins & Hill, 2007; Field et al., 2007) and, to a lesser extent, in father–infant interactions (Rodrigues et al., 2021). However, most studies have used behavioral indicators to investigate infants' emotion regulation. In order to have a comprehensive understanding of infants' emotional experience during parent–infant interactions and to understand how interactions are involved in infants' emotional regulation, studies also have used measurements of physiological indicators, such as vagal tone (Feldman et al., 2010; Ham & Tronick, 2009; Moore & Calkins, 2004; Pratt et al., 2015; Provenzi et al., 2015). Vagal tone is a measure of the modulating activity of the peripheral nervous system on the organs via the vagus nerve that can be indexed by heart rate variability (Laborde et al., 2017). There is an association between regulation of the parasympathetic branch of the autonomic nervous system and emotional regulation abilities (Santucci et al., 2008; Stifter et al., 2011). The polyvagal theory (Porges, 1995, 2001) postulates that when the environment is safe, the autonomic nervous system, through activation of the vagus nerve, exerts a parasympathetic influence on the heart (Porges, 1995, 2007). Through elevated vagal tone, the heart rate is slowed down, allowing for a state of calm that promotes social engagement (Porges, 1991). In the face of an increase in environmental demand, vagal tone decreases, resulting in a decrease in parasympathetic influence that allows for engagement of metabolic resources required to cope with the situation and adoption of appropriate behavior. When the demand decreases, vagal tone quickly resets to inhibit the influence of the sympathetic nervous system. The study of vagal tone provides information about the possibility and the ability to modulate the influence of the parasympathetic nervous system. According to Porges (1995), vagal tone at rest or during nonchallenging tasks is an indicator of the individual's vulnerability to stress, whereas the vagal response under challenging conditions is an indicator of adaptative functioning. Therefore, vagal tone has been proposed as an indicator of emotion regulation (Gentzler et al., 2009; Gottman & Katz, 2002; Porges et al., 1994; Zisner & Beauchaine, 2016) and was shown to be associated with behavioral measures of reactivity, emotional expression, and self-regulatory abilities, such as the ability to self-soothe or to use regulatory behaviors (Rattaz et al., 2022).

During parent–infant dyadic interactions, physiological variations have been observed in 3-month-old infants according to the quality of the interaction (Moore & Calkins, 2004). The quality of parent–infant interactions depends in part on the way parents adjust their behavior to the infant. Adjusted parental behaviors are aligned with the infant's emotional signals and state, whereas unadjusted parental behaviors are not. Adjusted parental behaviors and positive interactions are associated with high vagal tone (Feldman et al., 2010; Pratt et al., 2015; Provenzi et al., 2015), whereas unadjusted parental behaviors are related to low vagal tone or unusual patterns of vagal regulation (Bazhenova et al., 2001; Feldman et al., 2010; Ham et Tronick, 2009). These unadjusted interactions often are characterized by intrusive or withdrawn behaviors from the parent (DePasquale & Gunnar, 2020) and may constitute a disruptive experience for the infant. Intrusive behaviors include aspects of overstimulation, such as too much physical proximity, or unpredicted behaviors, whereas withdrawal behaviors include aspects of understimulation, physical distance, or lack of vocalization. These behaviors are considered stressful, as intrusive behaviors tend to go beyond infants' regulatory abilities, and withdrawn behaviors lead to the withdrawal of the parent from the interpersonal regulatory process, leaving the infant to regulate on his or her own, of which the infant is not yet capable. Therefore, intrusive and withdrawn parental behaviors have in common that they do not allow the infant to regulate because in both cases, the parent is not fulfilling his regulatory role with the infant. Consequently, these types of behaviors are associated with behavioral and physiological stress responses in the infant (Bugental et al., 2003; Feldman et al., 2010; Field, 2010; Wu & Feng, 2020) and do not permit the infant to maintain an accurate level of arousal and attention in the interaction (Wimbarti, 2006). In the face of an intrusive or withdrawn parental behavior, it therefore is likely that the infant withdraws from the interaction (Dollberg et al., 2006; Guedeney et al., 2011) which also will have an impact on the infant and the course of the interaction. An IWPB may be well tolerated by the infant, which will not cause any disruption of the interaction, with the infant remaining socially engaged with the parent. However, the infant may also show a reaction to the parental behavior, such as closing the eyes, turning the head away, or crying, which will affect the ongoing interaction and cause a disruption, which will also disrupt the interpersonal emotion regulation process the infant needs.

Physiological studies have focused mainly on mother–infant dyadic interactions, and only very recently in father–infant interactions (Puglisi et al., 2023). However, infants' social experiences are not limited to interactions with one parent only. Many infants experience complex social interactions such as triadic interactions on a daily basis, for example, when they experience interactions when both parents are present. The presence of both mother and father can give rise to relational family dynamics that cannot be observed in the presence of one parent only. For example, parents do not behave the same way when they are alone with the infant than when the other parent is present (Udry-Jorgensen et al., 2016). Therefore, the mother–father–infant triad is not limited to the addition of the mother–infant and the father–infant dyads. A few studies have investigated the influence of family-level relational processes and infants' physiological regulation by focusing on the consequences of marital conflict on the child. Higher levels of marital conflict have been associated with lower vagal tone and poorer vagal regulation in 6-month-old infants (Moore, 2010; Porter & Dyer, 2017; Porter et al., 2003), suggesting that exposure to conflict may influence physiological processes involved in emotion regulation. However, these studies only assessed the conflict in the marital relationship, and even if it may be indicative of a negative emotional climate in the family, they did not observe directly the way the family interacted together, in mother–father–infant triadic interactions. Studies have shown that the relational processes in triadic interactions have unique qualities and a unique influence on infants' socioemotional development that cannot be inferred from the study of dyadic interactions only (McHale & Lindahl, 2011). Indeed, whereas dyadic interactions allow one to study how parents are with their infant, triadic interactions allow one to study how parents are *together* with the infant. Therefore, the observation of triadic interactions gives access to specific interactional processes that are not available when observing a dyadic interaction.

The quality of the triadic relationship involving two parents and a child can be captured through the construct of family alliance. The family alliance is defined as the degree of coordination reached by the two parents and the child when they complete a task (Fivaz-Depeursinge & Corboz-Warnery, 1999). In the family alliance model, the quality of the family alliance depends on the achievement of four interactive functions (participation, organization, focus, and affective sharing) that are imbricated hierarchically. The Lausanne Trilogue Play (LTP; Fivaz-Depeursinge & Corboz-Warnery, 1999) is the observational paradigm that was specifically designed to assess family alliance. In the LTP, the family is asked to interact in a particular setting. The parents and the infant are seated in an equilateral triangle. Parents sit on regular chairs, whereas the child sits in a swivel and reclining chair, which allows parents to adjust its position according to the child's motor development. The position of the seat also can be adjusted according to the scenario of the play, as the chair can be oriented toward one parent, toward the other, or between them. Another characteristic of the LTP is that the family is asked to interact following a four-part scenario. In the first part, one parent is asked to interact with the child while the other parent simply remains present. In the second part, they switch roles, and then move on to the third part in which the triad interacts together. Finally, the parents are asked to have a conversation with each other and it is the child's turn to simply remain present. Analyzing the LTP according to the four interactive functions mentioned allows for an assessment of the family alliance, that can be categorized as being "cooperative," "conflicted," or "disordered." Cooperative families are characterized by cooperation, support, and cohesion. Conflicted families are characterized by competition and conflict. Finally, disordered families are characterized by exclusion and disengagement. Conflicted and disordered families are considered to have problematic alliances (Favez et al., 2011). They are indicative of difficulties in creating an optimal context for triadic interactions and are characterized by more unadjusted parental behavior such as overstimulation, intrusive behaviors, competition, withdrawals, or understimulation. Longitudinal studies have shown that a better quality of the family alliance, assessed in the LTP at several time points (prenatally and at 3, 9, and 18 months postpartum), is predictive of children socioemotional outcomes in the long term, such as a better theory of mind at 5 years (Favez et al., 2012) and better social cognition in adolescence (Tissot et al., 2022).

Until recently, studies about the influence of triadic interactions on infants socioemotional functioning have been conducted only with questionnaires or observable behaviors in the child. We recently investigated the influence of family alliance on infants' vagal tone during triadic interactions (Rattaz et al., 2023), and results showed that a higher quality of family alliance was associated with higher vagal tone in infants and that this effect was no moderated by the sensitivity of the parents. Two important contributions can be drawn from these results: first, the addition of physiological measures in this study of emotion regulation gives more information regarding the process underlying the association between triadic interactions and infants' socioemotional functioning; and second, the influence of the family alliance exerts on infants' vagal tone is over and above parental sensitivity. As mentioned above, families with problematic alliances tend to present more unadjusted parental behavior, and these behaviors and their influence on children only have been studied dyadic interactions, and never during triadic interactions. The amount of intrusive and withdrawn parental behaviors that are observed in problematic family alliance could be the interactional process at work in the association between family alliance and infants' vagal tone.

In summary, previous studies have shown that the quality of parent–infant interactions is associated with infants' behavioral and physiological emotion regulation. Some parental behaviors, such as intrusive or withdrawn behaviors, are associated with infants' physiological regulation. Recently, the quality of the triadic interactions has been shown to be associated with infants' vagal tone. However, to date, no study has investigated the interactional process, such as intrusions or withdrawals from the parents during triadic interactions, to explain the association between triadic interactions and physiological indicator of emotion regulation in infants.

The aim of this study was to investigate further the association between family alliance and infants' physiology, by looking at the mediating role of IWPBs during triadic interactions. We expected family alliance to be associated with infant's vagal tone during triadic interactions and for infants of families with a greater family alliance to show a higher vagal tone than that for infants of families with a lower family alliance. We also expected family alliance to be associated with the number of IWPBs during triadic interactions, with fewer IWPBs in families with a higher family alliance than in families with a lower family alliance, and with a smaller impact of these behaviors on the infant and the ongoing interaction in families with a higher family alliance than in families with a lower family alliance. Finally, we expected the association between family alliance and infants' vagal tone to be mediated by the number of IWPBs during triadic interactions.

2 | METHOD

2.1 | Participants

The participants were a convenience sample of 82 dual-parent families. The mean age of parents was 34 years for the mothers ($M = 33.78$, $SD = 4.04$) and 36 years for fathers ($n = 74$ due to missing data, $M = 35.93$, $SD = 5.76$). The infants were 43 boys and 39 girls ($M = 15.4$ weeks, $SD = 1.25$). Mothers ($n = 70$ due to missing data) had mostly completed a college degree (65%) and 80% were employed prior to maternity leave, 57% full time. Among the fathers ($n = 65$ due to missing data), 43% had completed a college degree and 95% were employed, 85% full time.

2.2 | Procedure

The parents were recruited during pregnancy at the maternity department of the Geneva University Hospitals by a midwife around the 37th week of pregnancy. The only inclusion criterion was to ensure that the parents spoke French fluently enough to fill in documents and questionnaires. The research was presented to the mothers and fathers and a consent form signed. They were then asked to fill an online questionnaire with their sociodemographic information. Families were invited to a laboratory session when the infant was between 3 and 4 months old. This age range was selected because infants are highly interested in face-to-face interactions and are capable of some self-distracting/self-soothing behaviors (turning head away, bring their hand to their mouth, etc.) but still highly depend on the parent to help them regulate (Kopp, 1989). At their arrival, the infant was placed on a changing table and the experimenter installed three pediatric electrodes on the infant's chest in order to record an electrocardiogram (ECG). Parents were then asked to play with their infant by following a paradigm in four parts, inspired by the LTP (Fivaz-Depeursinge & Corboz-Warnery, 1999). In the first part, one parent played with the infant for 2 min, while the other parent was outside the room. In the second part, the parents switched roles. During the third part, the two parents played together with the infant for 2 min. Finally, parents had a discussion together with the infant next to them for 2 min. At the end of the interaction, the electrodes were removed from the infant and parents had to fill in a form to receive online self-report questionnaires. The original LTP paradigm was modified in this study for two reasons. The first was for the collection of physiological data. In the LTP, the infant is seated in a pediatric chair designed to hold a 3-month-old infant in a sitting position. However, in this position, we were not able to get a clear ECG signal. Therefore, we decided to lay the infant down on a changing table, which is also a validated setting to assess family alliance (Rime et al., 2018). The second reason was that we decided to modify the first and the second parts of the LTP in order to get separate dyadic and triadic interactions. The present study focuses on the triadic mother–father–infant interaction (third and fourth parts).

2.3 | Measures

2.3.1 | Family alliance assessment scales

We assessed the family alliance through observation during the third and fourth parts of the modified LTP. The family alliance assessment scales (FAAS; Favez et al., 2011) are an observation tool for mother–father–infant interactions that aims to assess family alliance. The first part of the assessment consists of the classification of the interactive patterns observed in the triadic interaction into three different alliance categories (cooperative, conflicted, or disordered alliance). The second part of the assessment consists in rating specific behaviors shown by families during the modified LTP on 3-point scales: gazes, postures, implication of each partner, coconstruction, parental scaffolding, family warmth, validation of the child's emotional experience, authenticity of the expressed affects, and communication mistakes during shared activities. A total score is computed by summing the scores on these scales (range 0 to 18, $\alpha = .82$). A higher score indicates a high family alliance. Both the family alliance category and the family alliance score can be used as an index of the quality of the family alliance. In the present study, we chose to use the family alliance score, as it is considered a continuous variable and was therefore more suitable for the statistical analyses planned. The sample was coded by a senior coder, and a second coder double-coded 47% of the sample (41 videos of a total sample of 88). Both coders (first and third author) followed a 2-day training and have been certified in the use of the coding scale. The intraclass correlation coefficient (ICC) (two-way random, absolute agreement) on the family alliance score was good, with a coefficient of .79 (Koo & Li, 2016).

2.3.2 | Intrusive/withdrawn parental behaviors

IWPBs were coded by using a grid designed to identify parental behaviors of intrusion (overstimulation, physical intrusion, loud vocalizations, control, exaggerated expressions/affects) and withdrawal (understimulation, body distance, lack of vocalizations, averted gazes, facial expressions) in dyadic and/or triadic settings. The coding was done in slots of 5 s. For every intrusive or withdrawn parental behavior, an "impact" score was rated from 1 (*weak impact*) to 4 (*strong impact*) on the basis of the infant behavioral response (blinking, frowning, closing eyes, turning head, pushing parent away, screaming, crying, etc.) and the perturbation of the ongoing interaction following the IWPB. For example, an impact score of 1 was attributed if the infant flinches slightly in response to a parent's intrusive behavior but did not show sign of distress or disengage from the interaction. On the contrary, if the infant showed signs of distress in response to a parent's behavior, disengaged from the interaction and failed to return to the interaction, a score of 4 was attributed. For each family, we computed two variables: the frequency of the IWPBs on the overall interaction and the mean impact of these IWPBs in the sequence. One trained coder coded all videos, while another trained coder double-coded one third of the sample (30 videos of a total sample of 90). The coders (first and third author) practiced coding on 30 videos from another sample, to ensure that they had mastered the coding system before coding the families in this sample. Concerning the presence or absence of IWPBs in each time slot of 5 s, the interrater agreement was considered moderate, with a Kappa of .613 (McHugh, 2012). Concerning the impact of these behaviors on the infant and the interaction, we computed the interrater reliability for each time slot in which the occurrence of an IWPB had been coded commonly by both raters. An ICC computed on these data (two-way random, absolute agreement) yielded satisfactory results, with an ICC of .71. The present study focused on the IWPB observed during the 2-min mother–father–infant interaction.

2.3.3 | Vagal tone

The infant's cardiac activity was recorded during all parts of the paradigm by using an ECG. Data were collected with a Biopac MP160 system (Biopac Systems, Inc.) and recorded on AcqKnowledge 5.0 software (Biopac Systems, Inc.). During data collection, triggers were placed at the beginning and end of each of the 2-min parts of the interaction. Each of these segments was then extracted from the software. The ECG signal was processed on Kubios HRV v2.2 software to obtain the cardiac variability indicators, which reflect vagal tone. The software provides an automatic beat detection that can be corrected manually when the number of misdetections is limited. When the correction could not be done manually, a threshold-based beat correction algorithm was used to correct the signal. The correction aims to replace the artefacts with interpolated values. The corrections always were made using the lowest possible correction level. Analyses allowed us to derive the root mean square of successive differences (RMSSD), which represents the activity of the parasympathetic system and therefore is considered widely to be a valid measure of vagal activity (Laborde et al., 2017). The present study focused on the mean RMSSD calculated during the 2-min mother–father–infant interaction.

2.4 | Statistical analyses

First, we conducted descriptive statistics and correlational analyses. As there were missing data in sociodemographic information for both mothers and fathers, we conducted a missing data analysis. The Little's Missing Completely at Random (MCAR; Little, 1988) test was not significant, $\chi^2 = 8.563$, $df = 13$, $p = .805$, indicating that data were missing completely at random. Second, we used structural equation modeling techniques to estimate a model that tested whether the family alliance score was associated with the infants' RMSSD, and whether this association was mediated by both the number and the impact of IWPBs. The nature of our data, in particular the variable related to the impact of IWPBs, was called for specific analyses. Indeed, the fact that the "impact" variable was calculated for each triad as the mean impact of IWPBs on the overall sequence resulted in a very specific distribution of scores. Triads in which no IWPB was observed (i.e., scoring 0 on the frequency of IWPBs) obtained a score of 0 on this variable. In turn, families for which the frequency of IWBPs was 1 or more obtained a score ranging from 1 to 4. This specific distribution required the use of a hurdle model (Mullahy, 1986). A hurdle model separates the distribution of a variable into two parts: The first variable is the probability of a value of zero, and the second is the probability of the nonzero values. These two parts are modeled in two separate variables, one being binary and the other continuous. In the context of our data, the binary variable, named *IWPB presence*, determined the absence or presence of IWPBs during the interactions. The second variable created, named *IWPB impact*, represented the mean impact of IWPBs (ranging from 1 to 4). Of note, the third variable, that is, the number of IWPBs, is labeled *IWPB frequency* in the rest of the manuscript.

We tested a mediation model, which included a direct effect of family alliance scores on RMSSD and three indirect mediation pathways through IWPB presence, IWPB impact, and IWPB frequency. Of the sociodemographic variables available (infant's age, parents' education, parents' employment status, infant's gender), only the infant's gender was correlated with the variables of interest. Therefore, we included the infants' gender as exogenous variable in the model to control for its potential influence. The presence of mediation effects was established by comparing the significance of direct, indirect, and total effects.

We computed descriptive statistics and correlational analyses by using SPSS 25.0, and we estimated mediation models within a structural equation modeling framework by using Mplus 8.3 (Muthén & Muthén, 2017). Of note, the IWPB frequency was treated as a count variable that followed a negative binomial distribution. We tested mediation models using maximum likelihood estimator and computed bias-corrected bootstrap 95% confidence intervals (CI) based on $n = 5000$ samples, which is suitable to estimate models with nonnormally distributed data (MacKinnon et al., 2004). We relied to the bias-corrected CIs to determine the significance of the parameters in the model (the effect is

TABLE 1 Descriptive statistics.

Variable	*n*	Min.	Max	*M*	*SD*	Skewness	Kurtosis
FA score	82	3	18	12.30	3.89	–.552	–.750
RMSSD	82	2.80	16.97	10.44	3.29	–.092	–.675
IWPB	82	0	21	5.09	5.63	1.344	.895
IWPB impact	82	0	4	1.38	.96	.712	–.739

Abbreviations: FA, family alliance; IWPB, intrusive/withdrawn parental behaviors; RMSSD, root mean square of successive differences.

TABLE 2 Correlations between study variables.

Variable	1.	2.	3.	4.	5.
1. Infant's gender	1	–.013	–.044	.234*	–.060
2. FA score		1	.387**	–.378**	–.338**
3. RMSSD			1	–.163	–.304**
4. IWPB				1	.569**
5. IWPB impact					1

Abbreviations: FA, family alliance; IWPB, intrusive/withdrawn parental behaviors; RMSSD, root mean square of successive differences.

considered as significant CIs do not contain). Mplus does not provide absolute indices of fit for models that contain count variables, and so no model fit statistics could be reported.

3 | RESULTS

3.1 | Descriptive statistics

The descriptive statistics for the study variables can be found in Table 1. Normative values of RMSSD during infancy in studies mostly are based on 24-h ECG recordings (Massin & von Bernuth, 1997; Patural et al., 2019), making these normative values difficult to compare with the 2-min segments in the present study. However, studies for small segments of 10- or 2-min ECG recordings when infants are at rest, RMSSD mean values of $M = 12.12$ ($SD = 4.07$; Arce-Alvarez et al., 2019) or $M = 16.57$ ($SD = 9.85$; Zeegers et al., 2017) were found, which is similar or a little higher than the values in the present sample. Correlations between the study variables can be found in Table 2.

3.2 | Mediation analysis

The results of the estimation of the mediation model can be found in Figure 1 and Table 3. The results showed a significant direct effect of family alliance scores on infants' RMMSD. This confirmed our first hypothesis, that higher family alliance score is associated with higher RMSSD in infants. Of note, infants' gender showed no significant effect on family alliance scores or infants' RMSSD. Concerning the links between the independent variables (family alliance score, as well as gender as control variable) and the mediators, results showed an effect of family alliance scores on the IWPB frequency and IWPB impact, as higher family alliance scores predicted lower IWPB frequency and a

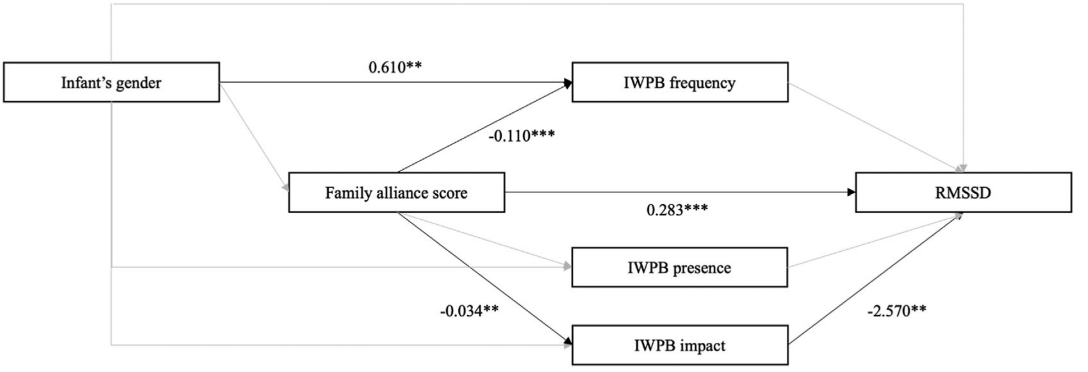

FIGURE 1 Results of the mediation model. *Note*: IWPB, intrusive/withdrawn parental behaviors; RMSSD, root mean square of successive differences. $^{**}p < .01$. $^{***}p < .001$.

TABLE 3 Standardized estimates of direct, indirect, and total effects of FA scores on infants' RMSSD.

				95% CI	
Type of path	Effect	Estimate	*SE*	Lower	Upper
Indirect	FA score ⇒ IWPB frequency ⇒ RMSSD	–.008	.008	–.028	.004
	FA score ⇒ IWPB presence ⇒ RMSSD	–.020	.213	–.461	.391
	FA score ⇒ IWPB impact ⇒ RMSSD	.087	.047	.020	.216
Component	FA score ⇒ IWPB frequency	–.110	.027	–.165	–.064
	IWPB frequency ⇒ RMSSD	.075	.064	–.044	.209
	FA score ⇒ IWPB presence	–.159	.135	–.448	.010
	IWPB presence ⇒ RMSSD	.128	.929	–1.782	1.912
	FA score ⇒ IWPB impact	–.034	.014	–.062	–.009
	IWPB impact ⇒ RMSSD	-2.570	.967	–4.441	–.651
Direct	FA score ⇒ RMSSD	.283	.076	.141	.442
Total	FA score ⇒ RMSSD	.341	.216	–.078	.761

Note: For the sake of readability, mediation paths involving infants' age and gender are not reported.
Abbreviations: CI, confidence intervals; FA, family alliance; IWPB, intrusive/withdrawn parental behaviors; RMSSD, root mean square of successive differences; *SE*, standard error.

lower mean impact of these behaviors. However, family alliance scores did not predict IWPB presence significantly. This confirmed our second hypothesis. Results also showed an effect of infants' gender on IWPB frequency, with a higher frequency for boys. Concerning the links between the mediators and the outcome variable, results showed that only the IWPB impact had a direct effect on RMSSD, whereas neither IWPB presence nor IWPB frequency showed a significant association with RMSSD.

Concerning the significance of the three indirect effects of interest, results showed that the indirect path from family alliance scores to RMSSD via IWPB impact was significant. As both the direct effect of the family alliance score on RMSSD and the indirect effect via IWPB impact were significant, our results suggest the presence of a partial mediation effect, partially confirming our mediation hypothesis.

4 | DISCUSSION

Our first aim in this study was to investigate the influence of the quality of mother–father–infant triadic interaction on physiological regulation. Results showed that family alliance is associated with infants' vagal tone, as triadic cooperation was associated with higher RMSSD in infants. Two conclusions can be drawn from this result. First, this study goes one step further in the investigation of family-level relationships and their association with infants' physiology. Results demonstrate that, in addition to what is already known in relation to the mother–infant and father–infant dyads, vagal tone is associated with interactive processes in the family triad. Second, this result is in line with the idea that the quality of triadic interactions influences children's outcomes. The present study shows its association with physiological processes. Studies on infants' vagal tone have shown an association between vagal functioning, either during a resting state or in response to a task, and outcomes such as emotional reactivity (Feldman, 2006; Ham & Tronick, 2009; Moore et al., 2009; Provenzi et al., 2015), regulatory behaviors (Calkins et al., 1998; Ham & Tronick, 2009; Perry et al., 2016), problematic behaviors (Calkins et al., 2007), and emotion regulation (Eiden et al., 2018; Feldman, 2015; Skibo et al., 2020). Thus, vagal functioning seems to be a key physiological process underlying socioemotional outcomes. Therefore, further studies should investigate its potential mediating role in the association between the quality of triadic interactions and infants' outcomes. Moreover, longitudinal studies are required to understand how these observed differences in vagal tone could influence the infants' socioemotional functioning in the long term.

The second aim of our study was to investigate whether the association between family alliance and infants' vagal tone was mediated by the frequency of IWPBs and their impact on triadic interactions. We had three variables related to IWPB: IWPB presence, IWPB frequency, and IWPB impact. Results showed that IWPB impact, but not IWPB frequency, seemed to mediate the link between family alliance and infants' RMSSD. Lower family alliance scores were associated with more IWPB frequency and with a higher impact of these behaviors on the interaction, which underlined the difficulties that these families had in coordinating in the interaction. However, although infants facing a higher IWPB impact on average showed a lower RMSSD, IWPB frequency was not associated directly with infants' RMSSD. These results thus suggested that the quantity of triadic miscoordinations might be of lesser importance than the magnitude of the miscoordinations. Although the nonsignificant link between IWPB frequency and infants' vagal tone was rather surprising, our findings are in line with the idea that interactive mistakes are likely to happen in parent–infant interactions and can be considered normative processes, as human interactions are rarely free from communicative mistakes. Studies in mother–infant dyads have shown consistently that interactions are mostly imperfect and miscoordinated (e.g., McFarland et al., 2020; Watson, 1985). However, when miscoordinations happen, it is the ability to repair and reengage in the interaction that permits the interaction to continue (Beeghly et al., 2011; Tronick & Cohn, 1989). This explanation also allows us to account for the result showing that the presence of IWPBs was associated with neither the family alliance score nor the infants' vagal activity, suggesting that these behaviors are likely to occur regardless of the quality of the family alliance, and that their simple presence is not necessarily a risk factor for the infant. As the IWPB impact was coded on the basis of infants' responses to each intrusion or withdrawal and how this response disrupted the interaction (e.g., turning head away, closing the eyes, pushing parents away, crying), the interactive process that explains the association between family alliance and infants' vagal tone lies in the perturbation of the ongoing interaction caused by parental behaviors, rather than in the parental behaviors themselves. Triadic interactions may contain intrusive or withdrawn behaviors, as long as they do not affect the quality of the ongoing interaction too much. The fact that family alliance was associated with a stronger IWPB impact on the infant and the interaction, which were in turn associated with lower RMSSD, might suggest that moments of mismatch that arise with intrusion or withdrawal in families with low family alliance scores might not be repaired quickly enough, leaving the infant unable to regulate. This explanation is consistent with the theoretical background of the family alliance concerning the idea that it is more difficult for families with a low alliance to set a positive interactive context for the infant.

This result also could be interpreted in light of the polyvagal theory (Porges, 1995). When vagal tone is high, the social affiliation system is available and individuals can use social communication to regulate their emotions

(Porges & Carter, 2017). If this affiliation system is not available, defensive strategies such as fight-or-flight behaviors are deployed. Infants in problematic families might not have the possibility to use their affiliation system to regulate, as the triadic interactions are not optimal. Thus, they might disengage from the interaction to regulate. Nevertheless, the result showing no association between IWPB frequency and infants' RMSSD was still surprising, as the polyvagal theory states that a stressful event in the environment will cause a decrease in vagal tone in order for the individual to cope with the event. It was expected to find lower mean level of vagal tone in infants confronted with more IWPB, which was not the case. This result could be explained by the fact that the families participating in this study were nonreferred families. There were few families whose observed functioning appeared to be totally maladaptive or close to pathological functioning. In a sample of higher risk families, we might have observed more variance in the frequency of intrusive or withdrawn parental behaviors, which might have led to different conclusions. However, these conclusions on infants' vagal functioning in this study should be taken with caution, as only a mean level of vagal tone was considered in the analyses, rather than an indicator of the vagal reactivity between a baseline and the triadic interaction. Indeed, the measurement of physiological indicators of emotion regulation is complex and the context in which it is measured has a major influence (Obradović & Boyce, 2012). Further studies should therefore investigate changes in vagal tone from a baseline to the interaction because this would provide a more complete indication of infants' emotional regulation during a triadic interaction (compared to a baseline) and could allow to draw more precise conclusions about the influence of the triadic context.

Finally, results showed only a partial mediation effect. Besides the IWPB impact, another explanation could be put forward to understand the association between family alliance and infants' vagal tone. First, in triadic interactions, infants can use triangular regulatory strategies to regulate; for example, when a parent is too intrusive, the infant might look at the other parent in order to share his or her affective state (Fivaz-Depeursinge & Favez, 2006; Fivaz-Depeursinge et al., 2005). This regulatory strategy might be more developed in infants of families with a better alliance than in infants of families with a lower alliance, where the parents are not able to coordinate in a way that permits the infant to regulate. Further studies therefore should examine the regulatory behaviors of infants in triadic interactions. In addition, the infants' initial physiological regulation competencies also should be investigated with longitudinal studies, as it has been shown that higher vagal tone at birth is a predictor of mother–infant synchrony at 3 months (Feldman, 2006). Infants' initial physiological regulation competencies could perhaps also play a role in the development of harmonious triadic interactions, with fewer unadjusted parental behaviors.

This study has strengths and limitations. Among the strengths, the use of physiological measurement is of particular interest for a better understanding of infants' socioemotional functioning when interacting with parents. Moreover, such a measurement provides a lead about the physiological process that might underlie the association between the quality of triadic interactions and socioemotional outcomes in infancy that has been shown in the literature. Several limitations also need to be mentioned. First, the study paradigm does not compare vagal tone during triadic interaction to a baseline. Even though interindividual differences in mean level of vagal tone during nonchallenging tasks are indicative of the infants' competencies to regulate physiologically (Porges, 1995; Porges et al., 1994), it does not provide information on vagal regulation per se. Therefore, the results of the present study encourage more precise investigation of dynamic regulatory processes in family interactions, by exploring changes in vagal tone from baseline to triadic interaction. Second, we only had one measurement time, which is not ideal for mediation analyses. However, this analysis provides a first step and interesting results for the investigation of the interactional process that could underlie the influence of the family alliance on the child's physiological regulation. Further studies should therefore test these associations longitudinally. Third, although the recruitment targeted a general population, most of the participants were highly educated, which might reduce the generalizability of the results. Additionally, we lack information on the parity of the families, which did not allow to control for differences between primiparous and multiparous families. Fourth, the context of the study (i.e., in a laboratory, with a given paradigm, filmed) might have been stressful for the families, making the parent–infant interactions less natural. Fifth, the relatively small sample size could lead to a lack of statistical power. A decrease in statistical power is mainly problematic because it can increase the risk of type II error (Nayak, 2010), which is not the case in this study, probably because the effect sizes were sufficiently large. However, further studies should replicate these results with a larger sample size. Finally, the interrater reliability for the IWPB was moderate, suggesting that there were some inconsistencies in the detection of IWPB between the coders, potentially stemming from the complexity of behavioral coding, especially within short time frames. The coding scale for the IWPB was developed for the present study, and the moderate interrater reliability suggests that some refinement should be made to enable the validation of the coding scale. The results should be considered in the light of these limitations, and further investigations should be made to improve the coding scale or the coding process.

Despite these limitations, this study is one of the first to investigate an association between triadic interactions and infants' vagal tone. Infants of families with a greater family alliance have higher vagal tone than do infants of families with a lower family alliance. This result stresses the importance of early mother–father–infant interactions, not only mother–infant interactions, in the development of emotion regulation processes that might be involved in later socioemotional outcomes. It also underlines the necessity to study triadic interactive processes that combine parents' and infants' behaviors rather than parental behaviors alone. Therefore, it is of particular interest for professionals working with families in perinatal care, as helping families to establish cooperative functioning might be crucial for infant development.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available and can be accessed in Yareta at: https://doi.org/10.26037/yareta:5v53qtn3wjhglhnaef2xnpczqe.

ETHICAL APPROVAL

The study and its protocol were approved by the Ethical Committee of the State of Geneva.

INFORMED CONSENT

We obtained written informed consent from all the parents included in the study.

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