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RESEARCH ARTICLE

The influence of the COVID-19 lockdown on infants' physiological regulation during mother-father-infant interactions in Switzerland

Valentine Rattaz[1] | **Hervé Tissot**[1,2] | **Nilo Puglisi**[1] | **Manuella Epiney**[3] | **Chantal Razurel**[4] | **Nicolas Favez**[1]

[1]Faculty of Psychology and Educational Sciences, University of Geneva, Geneva, Switzerland

[2]Department of Psychiatry, Center for Family Studies, Lausanne University Hospital and University of Lausanne, Lausanne, Switzerland

[3]Department of Obstetrics and Gynecology, University of Geneva Hospitals, Geneva, Switzerland

[4]Department of Midwifery, University of Applied Sciences Western Switzerland, Geneva, Switzerland

Correspondence
Valentine Rattaz, Faculty of Psychology and Educational Sciences, University of Geneva, Geneva, Switzerland.
Email: valentine.rattaz@unige.ch

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Abstract
In this study, we investigated the physiological regulation of vagal tone during dyadic and triadic parent-infant interactions in infants born before or around the COVID-19 lockdown in Switzerland. We hypothesized that there would be a decrease in vagal tone in triadic interactions compared with dyadic interactions, as triadic interactions are more complex and therefore more resource demanding. However, we expected this difference to be smaller for infants who experienced the period of confinement, as the lockdown led parents to spend more time at home. We also hypothesized that parents would have less stressful interactional events in the triadic interaction because they would be used to interacting with the child together. This study included 36 parents with their 3 month-old infants. Eighteen families met the study authors before the onset of the pandemic (pre-COVID) and 18 met them after its onset, having experienced a period of confinement during the infants' first 3 months of life (COVID). Results showed that the COVID group had no decrease in vagal tone during triadic interactions, whereas the pre-COVID group did. This difference could not, however, be explained by less stressful interactional events in triadic interactions,

as the COVID group showed more stressful interactional events in mother-father-infant interactions.

1 | INTRODUCTION

The management of the COVID-19 health crisis led to a lockdown in Switzerland between March and June 2020 (Federal Council, 2020). Schools, non-essential shops, sport facilities, restaurants, bars, and discotheques were closed, and gatherings were limited to a maximum of five people. Teleworking was massively implemented and, when this was not possible, there was a large recourse to partial unemployment. Borders were closed, and travel and going outside the home were to be kept to a minimum. The organization of a family with a child born in this period is therefore atypical because the parents have spent more time together with the child than is usually the case; paternal leave is indeed virtually non-existent in Switzerland (1 day only), whereas mandatory maternal leave is 14 weeks. The COVID-19 lockdown thus allowed the infant to be exposed to more frequent father-infant and mother-father-infant interactions in the first months after birth, in addition to mother-infant interactions. Because emotion regulation abilities in infancy are developed primarily through interactions with parents, the pandemic situation, in particular the 2020 lockdown, has created a context for the development of emotion regulation abilities that may prove to be different from that of other periods.

Emotion regulation is defined as the process responsible for monitoring, evaluating, and modifying emotional reactions, especially their intensive and temporal features, to accomplish one's goal (Thompson, 1994). Infants are born with immature emotion regulation abilities, needing the adult to regulate their emotions. Emotions in infants are used as messages sent to the caregivers; in response, caregivers adapt their behaviors 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, as infants grow up, a process of co-regulation involving the infants and their parents takes place. 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 quality of the relational context depends on the quality of parenting behaviors and on the ability of the parent to adjust his or her behavior to the infant's need and state. Parental sensitivity (Ainsworth et al., 1974) is defined as the parent's ability to notice and understand the infant's behavior and to offer an appropriate response. Sensitive parents are able to interpret the signals of their infant and respond appropriately. However, some parents might have difficulties in adjusting their behaviors in response to their infant in the interaction. A lack of sensitivity can lead parents to adopt withdrawal or intrusive behaviors in the interaction (DePasquale & Gunnar, 2020); the occurrence of such behaviors may constitute a stressful event for the infant. Intrusive behaviors include aspects of overstimulation, too much physical proximity or physical intrusiveness, or unpredictable behaviors. Withdrawal behaviors include aspects of understimulation, body distance, and lack of vocalizations. Overstimulation and understimulation have been shown to be associated with infants' withdrawal behaviors, such as gaze aversion (Brazelton et al., 1974; Field, 1977; Stern, 1974). Interactional stressful events have been observed, for example, in the interaction between depressed mothers and their infants (Crockenberg & Leerkes, 2003; Field, 2010; Goodman & Bumley, 1990; Tronick & Gianino, 1986), as well as in non-referred populations. An interaction with non-optimal stimulations (too intense, unpredictable, or low key) does not permit the infant to maintain an accurate level of arousal and attention in the interaction (Wimbarti, 2006). Maternal intrusiveness is associated with more negative affectivity in the infant (Wu & Feng, 2020) and with a higher physiological stress response (Feldman et al., 2010). Similarly, maternal withdrawal is associated with a higher physiological stress response in infants (Bugental et al., 2003).

To understand the infant's emotional experience during interactions with such stressful events, researchers have used physiological indicators, such as vagal tone (Bazhenova et al., 2001; Ham & Tronick, 2006; Moore & Calkins, 2004), as there is an association between regulation of the parasympathetic branch of the autonomic nervous system and emotion regulation abilities (Santucci et al., 2008; Stifter et al., 2011). The autonomic nervous system regulates homeostatic functions. It is composed of two subsystems: the parasympathetic nervous system (PNS) and the sympathetic nervous system (SNS; McCorry, 2007). The PNS is associated with growth and restoration, whereas the SNS is associated with the mobilization of resources to meet environmental demands. The antagonistic effects of these two systems therefore allow for a physiological state appropriate to the situation. Vagal tone is a measure of the modulation of the PNS on the organs by the vagus nerve. The vagus nerve is the 10th cranial nerve, originating in the brain stem and projecting to the various organs, including the heart and digestive system (Porges et al., 1994). It contains efferent and afferent fibers, allowing physiological regulation by dynamic feedback between the brain and the organs. The vagus nerve is composed of two branches, each of which is related to specific adaptive functions and behavioral strategies (Porges et al., 1994). The dorsal branch of the vagus nerve is associated with the regulation of visceral functions, and the ventral branch is associated with attention, emotion, and communication processes.

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 a stressful event, vagal tone decreases, resulting in a decrease in parasympathetic influence that allows for the engagement of metabolic resources required to cope with the situation and the adoption of appropriate behavior. When the stressor decreases, vagal tone quickly resets to inhibit the influence of the SNS. Because vagal tone responds to changes in the body's needs, increasing or decreasing its influence, it is considered a valid indicator of stress, as well as of the ability to organize one's physiological resources in an appropriate manner in response to environmental stimuli (Porges, 1995). The polyvagal theory associates autonomic nervous system functioning with emotional functioning. Baseline levels of vagal tone, as well as vagal reactivity, are associated with behavioral measures of reactivity, emotional expression, and self-regulatory abilities (Porges et al., 1994). Vagal tone is thus proposed as an indicator of emotion regulation abilities. From a developmental perspective, vagal tone increases in the early years as affect self-regulation skills improve (Porges, 1991).

When considering the interpersonal component of emotion regulation development, vagal tone is an important input into the study of early parent-child interactions. Physiological variations have been observed in infants in accordance with the quality of parent-child interactions (Moore & Calkins, 2004). When parental behaviors are adjusted to the attentional and emotional state of the infant and the interaction is marked by positive behaviors, infants' vagal tone is high. On the other hand, in response to stressful interactions, vagal tone tends to decrease. For example, using the Still-Face Paradigm, Tronick et al. (1978) showed that when mothers keep a still face, 5 month-old infants have a decrease in vagal tone in comparison to a normal interaction (Bazhenova et al., 2001; Ham & Tronick, 2006). Until now, physiological studies focused mainly on mother-infant dyadic interactions. However, infants' social interactions are not limited to mother-infant interactions. Most infants experience more complex interactions, such as mother-father-infant interactions. These triadic interactions are more complex than dyadic interactions (Fivaz-Depeursinge & Corboz-Warnery, 1999), for the parents as well as the infant. Indeed, triadic interactions require the infant to share attention between the parents and to deal simultaneously with two sources of stimulation; therefore, the infant has to use more regulatory resources in order to stay engaged in the interaction. Triadic interactions also require the parents to coordinate their behaviors directed to the infant. Studies on coparenting have shown that the way that parents coordinate their interaction with their infants influences the infant's psychological functioning (Favez et al., 2006, 2012; McHale & Rasmussen, 1998). However, these studies focused only on behavioral indicators, which does not allow access to the emotional experience of infants while interacting with their parents. To date, no study has assessed the physiological regulation of infants during mother-father-infant interactions.

For families with a child born around the pandemic, semi-confinement may have been a hassle as well as an opportunity to spend time together in the perinatal period, more than would have been the case in a regular situation because of the presence of the father. Studies on parental leave in Sweden showed that parents who equally shared parental leave reported having better coparenting than did parents who did not share their parental leave equally (Lidbeck & Bernhardsson, 2021); sharing parental leave also reduced stress related to parenting in fathers (Lidbeck et al., 2018). Therefore, having the opportunity to spend a greater amount of time at home with the infant in the perinatal period seems to be beneficial. The COVID-19 lockdown, in the context of the perinatal period, could have allowed parents to develop better parental coordination. This parental coordination could make these triadic interactions less resource demanding for infants, as they may contain fewer stressful interactional events (SIEs).

Our aim in the present study was to investigate the effect of the COVID-19 lockdown on infants' physiological regulation during dyadic and triadic interactions. The data presented here are part of a larger study that began in 2018 before the pandemic and was planned to last for 3 years; the COVID-19 health crisis was thus an unexpected opportunity to compare families before and after the crisis began. As the study targeted parents with a 3 month-old infant, it took place during their mandatory maternity leave in Switzerland; the lockdown thus mainly changed the presence of the father. Because triadic interactions require the infant to engage more regulatory resources than dyadic interactions do, this should be observable at a physiological level. Since vagal tone varies according to environmental demand (Porges, 1995), we hypothesized that a decrease in vagal tone would be observed in triadic interactions compared with that in dyadic interactions. We also hypothesized that the decrease in vagal tone would be smaller for infants in the COVID group, as they might be more used to interacting in a triadic context. Finally, we hypothesized that infants' vagal tone would be associated with SIEs and that there would be fewer SIEs in triadic interactions for the COVID group, as parents may have had more time to experience triadic interactions at home during the lockdown.

2 | METHOD

2.1 | Participants

The participants were a convenience sample of 36 dual-parent families. The infants were 16 boys and 20 girls. Mothers ($n = 31$ due to missing data) had mostly completed a college degree (80%) and 80% were employed prior to maternity leave, 60% full time. Of the employed mothers, 40% reported that they would decrease their employment rate after their maternity leave. Among the fathers, 68% ($n = 29$ due to missing data) had completed a college degree and 96% were employed, 86% full time.

No fathers reported a decrease in their employment rate after the child's birth. Of the 36 families, 18met the study authors before the pandemic (pre-COVID) and 18 met them after the pandemic started, having gone through a period of lockdown (COVID).

2.2 | Procedure

The parents were recruited by a midwife around the 37th week of pregnancy at the maternity department of the Geneva University Hospitals. We presented the research to the parents and interested participants signed a consent form. To avoid any performance bias, we explained to the parents that the study was focused on babies' emotions. Parents were informed that there would be an appointment at 3 months post-partum with a team of psychological researchers and that heart measurements would be recorded during a family play time. Families were invited to a laboratory session with the research team when the infant was between 3 and 4 months old. At their arrival, we reminded the parents of the context of the study and explained to them the course that the session would take. When the parents and the child were ready, 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). Then we asked the parents to play with their infant following a paradigm in three parts, inspired by the Lausanne Trilogue Play (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. Finally, during the third part, the two parents played together with the infant for 2 min. We informed the parents that their entire interaction would be filmed and indicated the position of the cameras in the room. They did not receive any particular instructions about the type of interaction; we simply asked them to avoid using objects and, if possible, not to carry, pick up, or put the infant in a sitting position on the table. At the end of the interaction, we removed the electrodes from the infant and parents had to fill in a form to receive online self-report questionnaires. We offered a debriefing in the form of video feedback to the parents who wanted it. The present study was conducted according to guidelines laid down in the Declaration of Helsinki, with written informed consent obtained from a parent or guardian for each child before any assessment or data collection. The study and its protocol were approved by the Ethical Committee of the State of Geneva.

2.3 | Measures

2.3.1 | Vagal tone

An ECG was recorded during all parts of the paradigm. Physiological data were collected with a Biopac MP160 system (Biopac Systems, Inc.) and recorded on AcqKnowledge 5.0 software (Biopac Systems, Inc.). The ECG signal was processed on Kubios HRV v2.2 software to obtain the cardiac variability indicators as indices of vagal tone. Analyses allowed us to derive the root mean square of successive differences (RMSSD), which represents the activity of the parasympathetic system and is therefore widely considered to be a valid measure of vagal activity (Laborde et al., 2017).

2.3.2 | Stressful interactional events

SIEs 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 (ref. Omitted for blind review). This coding system was created ad hoc on the basis of stressful parenting behaviors described in the literature (e.g., Brazelton et al., 1974; Feldman et al., 2010; Field, 1977; Stern, 1974; Wimbarti, 2006). For every 5-s interval, the research team coded whether a stressful interactional event happened. One trained coder coded all videos, while another trained coder double-coded around 30% of the sample (30 videos of a total sample of 85). The interrater reliability was assessed with a weighted kappa statistic. Interrater agreement was moderate, with a kappa of 0.613 (Landis & Koch, 1977; McHugh, 2012).

2.4 | Statistical analyses

First, we conducted descriptive statistics and correlational analyses by using IBM SPSS 25.0. Second, we used a latent growth curve model (GCM) approach to investigate how infants' RMSSD and SIEs evolved in the two groups (pre-COVID and COVID) across the three parts of the parent-infant interaction. This statistical approach is particularly suitable for analyzing developmental or repeated-measure data, as they consist of modeling trajectories for individuals from T1 to Tx (x corresponding to the number of waves in the study) on a given variable as a combination of their baseline status (modeled as an Intercept factor) and their amount of change between T1 and Tx (modeled as a Slope factor). To model a linear change in a given variable, we set the factor loadings linking the measures of the variable at the different time points and the Intercept factor to 1, whereas the factor loadings linking these measures and the Slope factor were set from *o* to *x*, in accordance with the number of time points (0, 1, 2, etc.). This approach allowed us to take into account both intra- and interindividual variations in these repeated measures (Bollen & Curran, 2006). In this study, we used a GCM framework to model the links between the trajectories of the RMSSD and SIEs experienced by the infants across the three parts of the play. We estimated a model that consisted of two separate GCMs (one for the RMSSD and one for the SIEs), thus including four factors: Intercept of RMSSD, Slope of RMSSD, Intercept of SIE, and Slope of SIE. To investigate the links between the trajectories on the RMSSD and the SIEs, we included in the model the estimation of the covariances between these four factors. This model was tested separately in the two groups (pre-COVID and COVID). We allowed the estimation of means and intercepts to vary across groups, whereas the variances and residual variances were held equal. We also compared this model with a second (nested) model in which all parameters were held equal across groups in order to test for the significance of estimating differences in the links between the trajectories of the RMSSD and the SIEs between groups.

The GCM analyses were estimated by using Mplus version 8.3. As the coding of SIEs results in a count variable, SIE variables followed a Poisson distribution. The Mplus program is perfectly able to handle models that combine variables with different types of distribution. Nevertheless, the inclusion of Poisson distributed variables in a model has a few consequences. First, Mplus does not estimate any residual variance for these variables. Second, and more important, Mplus does not produce any indices (chi square, comparative fit index, root-mean-square error of approximation, or standardized root-mean-square residual) that would allow us to assess the absolute fit of the models. However, we could at least compare the fit of the two models by using a chi-square difference test based on log-likelihood values and scaling correction factors (Satorra, 2000; for a full description of the procedure, see Satorra & Bentler, 2010), given that the models were estimated by using a maximum likelihood estimation with robust standard errors (ESTIMATOR = MLR in Mplus). Finally, it is also worth mentioning that Mplus computes separate *p* values when it estimates unstandardized and standardized coefficients for a given parameter, which may lead to situations in which the unstandardized and standardized values yield contradictory results (one being nonsignificant while the other is significant).

3 | RESULTS

3.1 | Descriptive statistics

The descriptive statistics for the study variables can be found in Table 1.

Studies on normative values of RMSSD during infancy are based on 24 h ECG recordings (Massin & von Bernuth, 1997; Patural et al., 2019), which makes these normative values difficult to compare with the 2 min segments in the present study. However, values of the present sample were similar or a little bit lower than values reported in other studies for small segments of 10–2 min ECG recordings when infants were at rest (Arce-Alvarez et al., 2019; Zeegers et al., 2017). Correlations between the study variables can be found in Table 2.

There were significant correlations between the RMSSD scores across the different parts of the interaction, as well as significant correlations between the SIEs across the different parts of the interaction. However, there was no significant correlation between infants' RMSSD and the SIEs in any part of the play. To control for a potential influence of time spent in confinement in the COVID group, we computed a variable for the number of days each infant spent in confinement; since this variable did not show any significant correlation with any of the variables of interest, it was not included in the subsequent models.

3.2 | Changes in RMSSD across the parts of the interaction

Results showed that the mean and variance of the Intercept factor were significant in the pre-COVID group ($M = 12.309$, $p < 0.001$, and $S^2 = 13.573$, $p = 0.001$) and in the COVID group ($M = 11.507$, $p < 0.001$, and $S^2 = 13.573$, $p = 0.001$). These results suggested that, in both groups, baseline RMSSD was on average different from 0, but that there was a significant heterogeneity between individuals, as some infants showed significantly higher RMSSD than others did. The mean of the slope factor was significant for the pre-COVID group ($M = 1.242$, $p < 0.0001$) but not for the COVID group ($M = 0.043$, $p = 0.891$). This difference was significant ($p = 0.002$). These results suggested that, for infants from the pre-COVID group, there was a decrease in RMSSD across the parts of the interaction, whereas this was not the case for infants in the COVID group. In other words, the infants had lower vagal tone during mother-father-infant interactions, compared with mother-infant or father-infant interactions, in the pre-COVID group than in the COVID group. In both groups, the correlation between the Intercept and Slope factors was significant and negative ($r = -0.684$, $p < 0.001$, in the pre-COVID group, and $r = -0.676$, $p < 0.001$, in the COVID group), showing that the individuals who had higher RMSSD at baseline were those who experienced a greater RMSSD decrease across the parts of the interaction Figure 1.

3.3 | Changes in SIEs across the parts of the interaction

Results showed that the mean and variance of the Intercept factor were significant in the pre-COVID ($M = 1.712$, $p < 0.001$, and $S^2 = 0.449$, $p < 0.001$) and in the COVID group ($M = 1.364$, $p < 0.001$, and $S^2 = 0.449$, $p < 0.001$). These results suggested that, in both groups, the average number of SIEs was different from 0, but that there was a significant heterogeneity between individuals, as some people showed significantly more SIEs than others did. The mean of the Slope factor was not significant for the pre-COVID group ($M = -0.019$, $p = 0.864$), but was significant for the COVID group

TABLE 1 Descriptive statistics of root mean square of successive differences (RMSSD) and stressful interactional events (SIEs)

	n		**Min**		**Max**		*M*		**SD**	
	Pre-COVID	**COVID**	**Pre-COVID**	**COVID**	**Pre-COVID**	**COVID**	**Pre-COVID**	**COVID**	**Pre-COVID**	**COVID**
RMSSD										
RMSSD_I	18	18	3.61	5.02	18.39	19.80	11.96	11.28	3.62	3.61
RMSSD_II	18	18	4.18	4.98	17.14	20.07	11.50	11.18	3.78	4.18
RMSSD_III	18	18	3.55	4.29	13.86	16.97	9.80	11.05	3.07	3.27
SIE										
SIE_I	18	18	1	0	19	25	7.55	4.77	5.24	5.65
SIE_II	18	18	0	0	21	16	5.83	6.72	6.89	4.02
SIE_III	18	18	0	1	23	23	8.00	11.61	5.96	5.77

Abbreviations: RMSSD_I, root mean square of successive differences in Part I (Dyad 1); RMSSD_II, root mean square of successive differences in Part II (Dyad 2); RMSSD_III, root mean square of successive differences in Part III (triad); SIE_I, stressful interactional events in Part I (Dyad 1); SIE_II, stressful interactional events in Part II (Dyad 2); SIE_III, stressful interactional events in part III (triad).

TABLE 2 Correlation matrix for study variables

	1.	2.	3.	4.	5.	6.
1. RMSSD_I	1					
2. RMSSD_II	0.762*	1				
3. RMSSD_III	0.643*	0.808*	1			
4. SIE_I	−0.107	−0.073	−0.153	1		
5. SIE_II	−0.224	−0.221	−0.179	0.433*	1	
6. SIE_III	0.013	0.027	0.102	0.560*	0.450*	1

Abbreviations: RMSSD_I, root mean square of successive differences in Part I (Dyad 1); RMSSD_II, root mean square of successive differences in Part II (Dyad 2); RMSSD_III, root mean square of successive differences in Part III (triad); SIE_I, stressful interactional events in Part I (Dyad 1); SIE_II, stressful interactional events in Part II (Dyad 2); SIE_III, stressful interactional events in Part III (triad).

*$p < 0.01$.

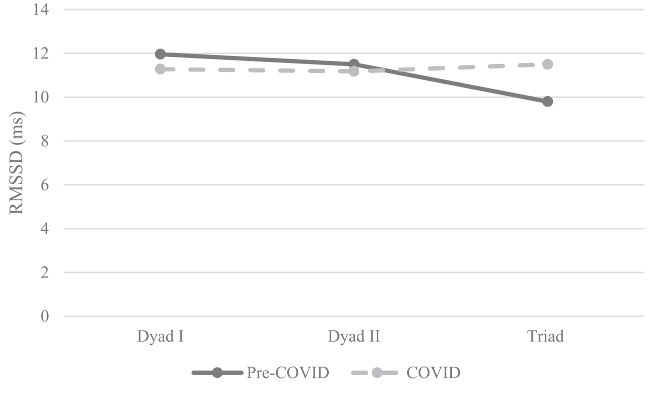

FIGURE 1 Changes in root mean square of successive differences (RMSSD) across the parts of the interaction in the pre-COVID and the COVID group

($M = 0.548$, $p < 0.001$). This difference between groups was significant ($p < 0.001$). These results suggested that there was no change in SIEs across the parts of the interaction in the pre-COVID group, whereas there was an increase of SIEs in the COVID group across the parts of the interaction. Moreover, in the COVID group, the significant correlation between the Slope and Intercept factors ($r = -0.611$, $p = 0.008$) showed that individuals who had lower amounts of SIEs at baseline were those who showed a greater increase of SIEs across the parts of the interaction Figure 2.

3.4 | Associations between SIEs and RMSSD

Results showed that the Intercept factor of RMSSD was associated with the Intercept factor ($r = -0.597$, $p < 0.001$) in the pre-COVID group. These results suggested that the baseline SIEs were associated with the baseline RMSSD, meaning that the more SIEs there were, the lower the RMSSD was at baseline. In turn, this association was not significant in the COVID group ($r = 0.248$, $p = 0.375$). The difference between the two groups regarding the link between RMSSD and SIEs at baseline was significant ($p = 0.027$), confirming that the association between RMSSD and SIEs at baseline was significantly stronger in the pre-COVID group.

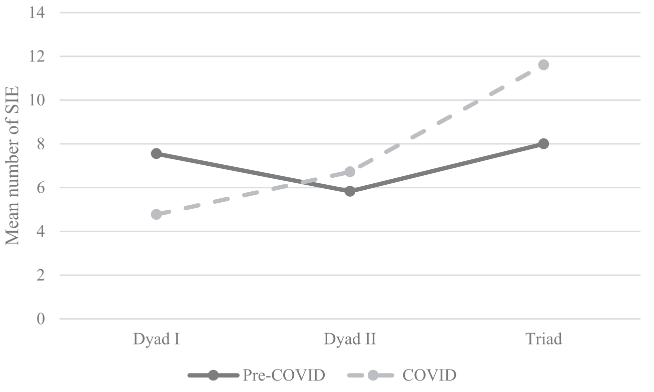

FIGURE 2 Changes in stressful interactional events (SIEs) across the parts of the interaction in the pre-COVID and the COVID group

In addition, in both groups, there were no significant associations between the Intercept factor of the SIEs and the Slope factor of the RMSSD ($r = 0.524$, $p = 0.153$, in the pre-COVID group, and $r = -0.393$, $p = 0.240$, in the COVID group) or between the Intercept factor of the RMSSD and the Slope factor of the SIEs ($r = -0.079$, $p = 0.878$, in the pre-COVID group, and $r = 0.037$, $p = 0.888$, in the COVID group). Even though there were no significant associations between the Intercept factor of the SIEs and the Slope factor of the RMSSD in the two groups, the results showed that this association was significatively different between the pre-COVID and the COVID group ($p = 0.044$). In the pre-COVID group, families with a high baseline of SIEs had infants with a lower decrease in the RMSSD across the parts of the interaction. In contrast, in the COVID group, families with a higher baseline of SIEs had infants with a larger decrease in the RMSSD across the parts of the interaction.

To investigate the relevance of estimating these group differences, we compared this model to an alternate model, in which all parameters were held equal across groups. The results of the chi-square difference test based on log-likelihood values and scaling correction factors were significant (TRd = 28.896, $p = 0.003$). These results suggested that the fit of a model that assumed differences between groups was significantly better than that of a model that assumed equality between groups.

4 | DISCUSSION

In this study, we aimed to investigate the impact of the COVID-19 lockdown on infants' physiological regulation during parent-infant interactions. We hypothesized that there would be a decrease in vagal tone from dyadic to triadic interactions and that the decrease would be smaller for infants in the COVID group than for those in the pre-COVID group. These hypotheses were confirmed above expectations, as we found no decrease at all in vagal tone for the infants in the COVID group. We also hypothesized that the smaller decrease would be explained by fewer SIEs in mother-father-infant interactions in the COVID group than in the pre-COVID group. This hypothesis was, however, not confirmed.

According to the polyvagal theory (Porges, 1995, 2001), when environmental demand requires an increase in resources, vagal tone should decrease in order to help the individual cope with the situation. As affect regulation in triadic interactions is more difficult to handle for infants (Fivaz-Depeursinge & Corboz-Warnery, 1999), we hypothesized that infants would have lower vagal tone in triadic interactions in order to mobilize the resources needed to deal with the interaction. The fact that the infants in the COVID group did not have significantly lower vagal tone during triadic interactions could mean that they do not perceive the interaction with mother and father as being more resource demanding than interactions with only one parent, or that they have better physiological regulation abilities than the infants in the pre-COVID group do. A possible explanation for these differences between the two groups lies in the second aim of the study, which was the hypothesis of less frequent SIEs during triadic interactions in the COVID group. However, contrary to our expectations, the SIEs were not less numerous in this group. Results indeed showed that there were no changes in SIEs across the parts of the interaction in the pre-COVID group, whereas there was even an increase in SIEs in the COVID group. Also contrary to our expectations, rather than improving coordination, the more frequent presence of the father may have resulted in elements of competition between the parents, especially in the perinatal period. Switzerland is a country in which roles still tend to be shared in accordance with the traditional gendered schema (the father as breadwinner, the mother taking on the role of child caregiver and housekeeper). Moreover, there is little direct structural help for families, so that the parental burden rests mainly on women (Bonoli, 2007). In the COVID group, this distribution has been challenged so that gatekeeping behaviors may have appeared, each parent trying to be the one who provides the infant with more stimulation, at the risk of being overstimulating and/or excluding the other: the father in order to show his engagement, the mother in order to maintain control according to social expectations (Fagan & Barnett, 2003; Van Egeren, 2003).

However, more SIEs does not translate into lower vagal tone in infants. Results showed that in the pre-COVID group, SIEs were associated with RMSSD, which was not the case for the COVID group. Even though families in the COVID group had a greater increase of SIEs across the parts of the interaction, infants did not seem to show an associated decrease in RMSSD. Therefore, the difference in RMSSD in the two groups cannot be explained by the SIEs. Several alternate explanations may be explored. First, the more frequent presence of the father implies that the infant has received more stimulations specific to father-infant interaction: Fathers indeed tend to be more engaged than mothers in physical stimulation and less predictable play (Lewis & Lamb, 2003), which has been shown to promote the development of particular aspects of infants' emotion regulation (Parke, 2002; Pleck, 2007). Infants in the COVID group could have developed better emotion regulation abilities by having their fathers more often present to interact with. Further studies should investigate the specific contribution for infants who have both parents present during the first months of life. Second, the infants in the COVID group could have better use of regulatory behavior such as triangular strategies (Fivaz-Depeursinge et al., 2005; Fivaz-Depeursinge & Favez, 2006). During triadic interactions, infants can use triangular bids in order to regulate themselves; 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. This triangular strategy might be more effective in the infants of the COVID group, as they could be more used to having their two parents available when in need of social regulation of affect. Infants in the COVID group might thus have found triangular regulatory strategies that protected them from the impact of parental stressful behaviors. This is in line with the polyvagal theory, which postulates that physiological regulation determines the range of behaviors available to respond to the environment (Porges, 1995, 2001) and that social regulation strategies are available to infants with optimal vagal regulation (Porges & Furman, 2011). Finally, the infants in the COVID group might have developed different behavioral strategies to regulate themselves. The involvement of the parents has an influence on the regulatory strategies used by the infants (Planalp & Braungart-Rieker, 2015). As parents in the COVID group were limited in their leisure or social activities, as well as travels during lockdown, they might have been more involved in their relationship with their infant, which might foster the development of emotion regulation strategies. Even though there does not seem to be differential regulatory behaviors used when interacting with the mother or with the father (Diener et al., 2002), it is possible that the exposure to different interactional contexts, such as mother-infant, father-infant, and mother-father-infant interactions, allows the development of better emotion regulation abilities. This is what the results of the present study suggest: The fact that the family is gathered together at home, because of the lockdown, is not neutral. It underlines the importance of family-level relationships.

This study was not initially designed to specifically assess the impact of the COVID pandemic. On the one hand, this context was an opportunity, as it allowed us to compare interactions in families before and during the pandemic. On the other hand, this was also the source of limitations for this study. First, the sample size was small. Because of the context, the midwife who was in charge of recruitment had to stop her research activities to focus on medical care in COVID-19 units. Thus, the participants in the COVID group included in this study were recruited just before recruitment had stopped, or much less regularly after the critical early phase of the pandemic, which considerably limited the enrollment of families. Moreover, some families refused to attend the 3-month appointment because of the transmissibility of the virus. With the small sample size, results need to be interpreted carefully. Second, we did not have any information about the presence of siblings in the family and about parental organization at home. During the COVID-19 lockdown, schools and daycare were closed and it is therefore possible that in the case of families with older siblings, the parents divided the tasks and did not necessarily spend more time in a triad. Third, the health crisis also caused many difficulties, including psychological and financial ones. Again, as assessing the impact of COVID was not the primary aim of this study, we did not evaluate difficulties specifically related to the pandemic. However, it should not be overlooked that for some families, the difficulties encountered could have had the opposite effect than the one investigated in this study, that is, difficulties in setting up parental coordination because of competing demands, the constant presence of each family member at home, the lack of private time, the anxiety-inducing nature of the situation, etc. Finally, two limitations regarding the measures used should be mentioned. The first limitation is the moderate interrater agreement on the coding of SIEs; work needs to be done to improve this agreement for future studies. The second limitation concerns the physiological measure of emotion regulation. Although vagal tone is often used in studies as the main indicator of emotion regulation, other indicators could have been considered given the systemic nature of emotion regulation involving physiological, affective, and social mechanisms (Thompson et al., 2008). This consideration is all the more important for the emotional regulation of young children, where contextual and extrinsic factors are crucial. Further studies should examine both physiological and observational processes involved in emotional regulation in the infant, considering, for example, vagal tone, along with behavioral aspects of emotion regulation and social regulation by the parents.

The aim of this study was to investigate the differences in physiological activation during mother-infant, father-infant, and mother-father-infant interactions in infants born before or after the beginning of the COVID-19 pandemic in Switzerland. Results showed that infants in the pre-COVID group had lower vagal tone during triadic interactions than did infants in the COVID group. These differences cannot be explained by the SIEs observed during the interaction. As the main difference caused by the COVID-19 lockdown was the greater presence of the father with the mother and the infant, it is important to focus on the specific contribution of the father in the first months of the child's life for the development of the child's emotional regulation capacities. These results encourage consideration of introducing parental leave after the birth of a child—which does not exist in Switzerland at the moment—since it seems to be beneficial for the child.

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ORCID

Valentine Rattaz https://orcid.org/0000-0002-6530-1758

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