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Higher heart rate variability predicts better affective interaction quality in non-intimate social interactions

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Abstract

Adaptive emotional responding is crucial for psychological well-being and the quality of social interactions. Resting heart rate variability (HRV), a measure of autonomic nervous system activity, has been suggested to index individual differences in emotion regulation (ER). As non-intimate social interactions require more regulatory efforts than intimate social interactions, we predicted that the association between HRV and affective interaction quality is moderated by the perceived intimacy of the exchange. Thus, we expected higher HRV to be particularly beneficial for affective interaction quality in non-intimate social interactions. Resting HRV was measured in the laboratory ($N = 144$). Subsequently, participants reported their affective interaction quality—as indicated by more positive and fewer negative emotions perceived in the self and the other—during an experience-sampling social interaction diary task. As predicted, in non-intimate interactions, individuals with higher HRV reported more positive and fewer negative emotions and perceived fewer negative emotions in their interaction partners. The results provide further insights into the relationship between HRV and emotional experiences during social interactions.

KEYWORDS

affective interaction quality, emotion regulation, heart rate variability, intimacy, social interaction

1 | INTRODUCTION

Aristotle already described humans as social animals (Aristotle, Politics, I, part 3). Individuals naturally seek the exchange with others and even more than that—a human being needs the companionship of others to survive (Bruhn, 1991; Tomasello, 2014; Wesselmann et al., 2012). Yet, social interactions are highly complex processes, especially due to the fact that they are replete with emotional exchanges and effective emotional communication is challenging at times. The context determines the specific benefits or costs of displaying a certain emotion. In some situations, certain emotional expressions are adaptive and appropriate, whereas in other situations, they may cause harm, impose stress, and consequently put strain on social relationships. For

Heidi Mauersberger and Jennifer L. Tune contributed equally to this study.

instance, displaying joy while interacting with a friend who has just experienced a misfortune is inappropriate and may permanently harm the relationship with the sad friend. Hence, the appropriate regulation of emotions is indispensable for adequate social functioning (Eisenberg et al., 2000; Gross, 2002) and thus for the mutual satisfaction of interaction partners and for affective interaction quality in general.

1.1 | Emotion regulation and affective interaction quality

Emotion regulation (ER) consists of regulating the intensity, quality, as well as the dynamic, and temporal characteristics of emotions, such that a desired emotional state is achieved, and goal-oriented behavior is facilitated (Thompson, 1994). Supporting the importance of ER for affective well-being during social encounters, Lopes et al. (2004) found positive associations between ER and positive feelings during social interactions, both with same-sex and opposite-sex interaction partners. This may be explained by the underlying cognitive processes that contribute to ER and that play a crucial role for socially competent behaviors (Riggs et al., 2006). Specifically, individuals performing better on the Stroop test or stop-signal task, which measure inhibitory control, are also better in regulating socially inappropriate or aversive emotions (Tabibnia et al., 2011; von Hippel & Gonsalkorale, 2005). Additionally, attention shifting and higher working memory capacity relate to more efficient cognitive reappraisal, expressive suppression of negative emotions (McRae et al., 2012; Schmeichel et al., 2008), and coping with stressful life situations (Stawski et al., 2010). Neuroimaging studies also confirm a considerable overlap between the regions within the prefrontal cortex involved in executive functioning and the regulation of emotion (e.g., Tupak et al., 2014).

In sum, individual differences in executive functioning may explain why ER decreases negative feelings and hence improves affective well-being during social interactions (such as a flexible focus of attention, which facilitates smooth communication in social interaction) and consequently who is better and who is worse at coping with environmental demands.

1.2 | Heart rate variability as a valid index for emotion regulation

The extent to which individuals are able to adapt their responses to environmental demands and, in turn, to efficiently navigate social interactions depends on the interplay between the two subsystems of the autonomic nervous system (ANS) (Levenson, 2014; Thayer & Lane, 2000). The sympathetic nervous system (SNS) has an excitatory effect on the body and dominates in situations in which the organism is required to use a high level of energy. The parasympathetic nervous system (PNS), on the other hand, is responsible for the conservation of resources, returning the organism to homeostasis and establishing a state of rest (Shaffer & Ginsberg, 2017). Heart rate variability (HRV) is a noninvasive marker of parasympathetic activity and hence of the autonomous flexibility of the organism (Appelhans & Luecken, 2006). An adaptive ANS is characterized by high HRV, whereas reduced HRV indicates an imbalance of the ANS (Birkhofer et al., 2004).

Porges' polyvagal theory (Porges, 1995) and the neurovisceral integration model by Thayer and Lane (2000), both emphasize the role of parasympathetically (vagally) mediated inhibition of arousal for effective emotional responding and suggest HRV as an index thereof (Appelhans & Luecken, 2006). Porges (2003) highlights the importance of vagal regulation in social behavior, emphasizing the role of the vagus nerve in regulating cardiac output to encourage or discourage social engagement and prosocial behaviors. The neurovisceral integration model by Thayer and Lane (2000) postulates that overlapping brain areas are involved in the regulation of cardiac activity as well as emotional and cognitive self-regulation processes. According to this model, HRV is used as a peripheral indicator of the functioning of these neural circuits, with higher HRV representing more efficient functioning, and therefore supporting flexible and goal-directed behavior in response to environmental demands (Balzarotti et al., 2017; Thayer et al., 2012).

Supporting the assumption that HRV is a biomarker for adaptive regulation during social encounters, recent studies found that brain regions important for emotion and self-regulation (Etkin et al., 2015) are also associated with higher HRV. For instance, individuals with higher HRV showed a stronger functional connectivity between the amygdala and the medial prefrontal cortex and a thicker right anterior midcingulate cortex (Sakaki et al., 2016; Winkelmann et al., 2017). Further, numerous studies found associations between HRV and emotion processing and regulation. Specifically, higher HRV is related to greater openness and less aggression (Zohar et al., 2013), more accurate emotion recognition (Quintana et al., 2012), better downregulation of negative emotions, use of adaptive ER strategies, and more flexible emotional responses (Balzarotti et al., 2017), as well as better accessibility of ER strategies (Aldao & Mennin, 2012). In contrast, lower HRV is related to a lack of emotion clarity and difficulties in ER and impulse regulation (Williams et al., 2015). Further, lower HRV is associated with various types of psychopathology as well as difficulties in interpersonal functioning (Balzarotti et al., 2017). Thus, individuals with higher HRV report suffering less from prosocial stress (Lischke et al., 2018) and are more likely to display prosocial behavior (Kok & Fredrickson, 2010) or rate themselves as more empathic and less alexithymic (Lischke et al., 2018) than individuals with lower HRV. Hence, individuals with higher HRV may feel more comfortable and experience more affective well-being during social interactions than individuals with lower HRV. Yet, the strength of the relationship between HRV and affective interaction quality may depend on the demands posed by the social situation. It is reasonable to assume that higher HRV may provide more benefits for individuals when they experience more stressful social encounters, for instance when they have to interact with unfamiliar others whose likely reactions they cannot predict.

1.3 | Heart rate variability's benefits for non-intimate social interactions

Social exchanges vary in their meaningfulness (or intimacy). Some interactions may be more superficial or non-intimate (for instance, we may greet a colleague and ask them about their previous days without profound interest), whereas other interactions may be experienced as more intimate (for instance, we may visit a friend and talk about the miseries and fortunes we experienced recently). Non-intimate social interactions should be more stressful compared to intimate interactions because unknown others may act in an unforeseeable and less predictable way (see, e.g., Hess et al., 2016). Indeed, superficial or non-intimate interactions are experienced as more challenging or stressful compared to intimate interactions (e.g., Lischke et al., 2018). Further, Spitzer et al. (1992) reported larger increases in cardiovascular activity in their participants during interactions with less-known interaction partners relative to interactions with close partners, implying higher levels of experienced stress. Similarly, Asendorpf (1989) reported that people are more inhibited and withdrawn around less-known interaction partners, probably as it is more difficult to understand and judge the intentions that unknown others signal through their emotions and to adequately react to these emotions. Thus, especially during non-intimate interactions, HRV may play a crucial role for the well-being of interaction partners and hence for affective interaction quality.

To summarize, non-intimate (in contrast to intimate) interactions pose higher ER demands. Consequently, individuals with higher HRV may feel more comfortable and report better affective interaction quality, as they are more skilled in coping with the potentially threatening non-intimate interactions than individuals with lower HRV. Up to date, no study has examined the differential effects of HRV for intimate versus non-intimate social interactions. The present study addressed the interaction effects between HRV and the intimacy of the social interaction on several indicators of affective interaction quality during a variety of social interactions.

1.4 | The present study

The aim of the study was to assess whether the relationship between HRV and affective interaction quality might be influenced by the degree of perceived intimacy of the social interaction using a multi-method design. Resting HRV is understood to be a psychophysiological (and non-invasive) marker of ER ability. This objective ER index limits biases that subjective assessments of ER typically suffer from (Mauss & Robinson, 2009). We measured affective interaction quality across a broad range of naturally occurring social interactions for several days using experience-sampling. Diaries, unlike retrospective reports, are less susceptible to biases in recollection (Bolger et al., 2003). Further, diaries capture contextual fluctuations and, hence, social interactions are described in a more accurate and comprehensive manner fostering the ecological validity of this method (Bolger et al., 2003). This approach presents a decided advantage over previous attempts to relate ER ability to social interaction quality based on retrospective reports.

Based on the considerations above, we expected that the degree of perceived intimacy would moderate the effect of HRV on affective interaction quality during social interactions. More specifically, we hypothesized that especially in non-intimate social interactions, higher HRV would be beneficial for the individual's affective interaction quality during the interaction, as indicated by more positive and fewer negative emotions experienced by the individual and perceived in their interaction partners.

2 | METHOD

2.1 | Participants and design

To detect a medium (to large) cross-level interaction effect (in two-level models) between HRV and intimacy with a medium random slope variance component and a power of at least .80, we initially recruited 152 individuals (who were requested to report on their affective interaction quality during social interactions on at least nine occasions; rule of thumb derived from Monte Carlo simulations: if 6[1] $\leq n$ [number of interac-

[1]We only included participants who reported on at least six social interactions (see below for more detail).

tions] ≤ 16, N [number of participants] should be between 90 and 150; Arend & Schäfer, 2019). This sample size slightly above the upper bound of 150 participants was chosen a) because the mean number of interactions was only slightly above the lower bound of six interactions and b) to compensate for potential loss in complex (diary) studies. We recruited via the participant acquisition server (Psychologischer Experimental Server Adlershof, PESA) of the Department of Psychology at Humboldt Universität, advertisements on a social networking website (Facebook), campus recruitment, and flyers. Four participants decided to discontinue participation (drop-outs) and four were excluded from analysis due to technical problems (e.g., equipment malfunction) or clerical error. The final sample consisted of 144 participants (38 men and three participants identifying as gender diverse) between the ages of 17 and 51 (M_{age} = 28.0 years; SD_{age} = 7.05 years).

The study was approved by the Institutional Ethics committee and was carried out in accordance with the guidelines of the Declaration of Helsinki (except for lack of preregistration), and the recommendations for good scientific practice of the Deutsche Forschungsgemeinschaft (German Research Foundation, DFG). All participants provided their written informed consent for each part of the study and were fully debriefed at the end. They participated individually and received either 10 course credits (psychology students) or 25 € for their participation. Participants were aware that they had the right to discontinue participation at any time that their responses were confidential, and that collected data would be stored in a pseudonymized way according to the European General Data Protection Regulation (GDPR).

2.2 | Procedure

One day prior to the laboratory session, participants completed an online questionnaire covering demographics and several individual difference measures not relevant to this research question.[2] Upon arrival at the laboratory, after providing informed consent, electrodes were attached. Then, participants were seated in a comfortable chair in front of a computer screen in a climate-controlled quiet room and watched a relaxing video during which cardiovascular activity was recorded (see below). Participants then completed an emotion perception task, which will not be reported here. Following this, participants received instructions for the diary. They were asked to report on the quality of their naturally occurring nontrivial social interactions for three consecutive days. Each day, participants received an email invitation to complete the diary task at three different times a day (12, 4, and 8 p.m.), with follow-up email reminders (2 h later) if no entry had been made. If the diary was not completed three times a day, the diary task continued for an extra day until at least nine interactions were reported or participants requested the end of the data collection. To be included, participants had to report on at least six interactions across three different days. At the end of the experiment, they were fully debriefed and all outstanding questions were answered by the investigator.

2.3 | Physiological measures

2.3.1 | Cardiovascular activity

Electrocardiography (ECG) was continuously recorded at a sampling rate of 1000 Hz while participants watched a relaxing video showing water lapping at a beach in the sunset. This method was used to acquire a measure of resting-state HRV, which is considered to be a proxy for the regulation of ANS activity (Thayer et al., 2012). During the video, participants were observed to retain usual breathing patterns. HRV was assessed based on the last 5 min of the 6-min video.

For the HRV recording, the skin was cleansed with rubbing alcohol and two prejelled Mindware Ag/AgCl snap disposable vinyl electrodes were placed on the participants' right collarbone and left lower rib and one prejelled Mindware Ag/AgCl snap disposable vinyl reference electrode was placed on participants' right lower rib. A Mindware BioNex Impedance Cardiograph amplifier with a bandpass filter of 0.5–100 Hz (and a 50-Hz notch filter) was used and the ECG signal was converted into R-wave intervals. Artifacts and recording errors were corrected manually. HRV was indexed by RMSSD (root mean square of successive differences between consecutive heart beats), a robust time-domain measure (Bertsch et al., 2012; Shaffer et al., 2014) that is less affected by respiratory influences than high frequency parameters (Hill & Siebenbrock, 2009). Four participations were excluded from analysis due to excessive artifacts in the HRV recording (n = 3) or technical problems during the recording (n = 1).

2.4 | Subjective measures (diary task)

Participants were instructed to complete a short daily diary form containing several questions about the last

[2]This study is part of a collaborative research project by Humboldt-Universität zu Berlin and Jagiellonian University in Kraków on narcissism and emotional mimicry.

(non-trivial) social interaction they had experienced before receiving the email reminder.[3] The diary questions (see Mauersberger et al., 2015) were programmed in *formr*, an open-source software for complex surveys hosted on servers at the Georg-August-Universität Göttingen (Arslan et al., 2020). Participants were able to answer diary questions using their own smartphones, tablets, or computers. Three times per day (at 12, 4, and 8 p.m.) for three consecutive days, participants received a link to a short survey with questions about the last social interactions they experienced prior to the notification. If 3 days had passed by and participants had not filled out the diary nine times, the data collection automatically continued for extra days (until participants reported on at least nine social encounters or requested a stop of the data collection). A small but notable number of participants had not been able to obtain the minimum number of nine diary entries within 2 weeks of data collection. Hence to avoid losing participants, we lowered the threshold to six entries.

Three participants were excluded from analysis due to insufficient number of diary entries (less than six entries) ($n = 1$) and inattentive response patters/"straightlining," that is, selecting the same response option for all questions ($n = 2$). Participants answered questions about the interaction as well as about their own emotions and the emotions of their interaction partner during the interaction. If an interaction occurred that involved multiple people, participants were instructed to focus on their main interaction partner and only answer the questions about the one-on-one interaction.

2.4.1 | Interaction description

For each social interaction, participants reported the length of the interaction in minutes and rated the level of intimacy on a 7-point Likert scale ranging from 1 = *distant* to 7 = *intimate*, describing the perceived intimacy between the participant and their interaction partner. The median length of the interactions was 30 min. On average, interactions were reported to be somewhat more intimate ($M = 4.53$, $SD = 0.70$) than the midpoint of the scale (4).

2.4.2 | Affective interaction quality

Participants described their own emotions and their perception of the emotions of the interaction partner on 7-point Likert scales ranging from 1 = *not at all* to 7 = *very much*.

Own emotions

In reporting their own emotions, participants answered the following two items: "During the interaction I felt: happy/cheerful/in a good mood" and "During the interaction I felt: sad/uncomfortable/depressed."

Other's emotions

To rate their perception of the interaction partner's emotions, participants were presented with the following two items: "Did he/she show positive emotions?" and "Did he/she show negative emotions?"

2.5 | Statistical analyses

We calculated for each of the four affective interaction quality indices, a random-intercept, fixed-slope linear-mixed effects model using lme4 (Bates et al., 2015) in R with RMSSD, level of intimacy as well as the interaction between RMSSD and level of intimacy as continuous predictors controlling for length of interaction. All continuous predictor variables were grand-mean centered.[4] Restricted Maximum Likelihood was used to fit the model.

3 | RESULTS

We hypothesized that higher HRV would be beneficial for the individual's affective interaction quality (as indicated by more positive and fewer negative emotions experienced by the individual and perceived in their interaction partner) during non-intimate social interactions. Means and the ratio of the between-person to total variances (ICC1) as well as correlations between study variables are presented in Table 1. Given the hierarchical nature of the data, we present both between-person (above the diagonal) and within-person (below the diagonal) correlations.

3.1 | Own emotions

The linear-mixed effects models predicting participants' own positive and own negative emotions showed that the

[3]Note that the data collection took place prior to the COVID-19 pandemic.

[4]Given that our main research question focused on how intimacy of a social interaction moderates the between-subject effect of HRV on affective interaction quality, we also applied grand-mean centering to the moderator variable intimacy. This ensured that both the between-subject and within-subject source of variance in this regressor were considered (Enders & Tofighi, 2007).

TABLE 1 Summary statistics and correlations between variables

	Means	ICC	2	3	4	5	6	7	8
1 Age	27.8		−0.19*	0.02	−0.11	−0.16	0.05	−0.18*	0.20*
2 RMSSD	46.1			0.06	0.05	0.14	−0.10	0.07	−0.14
3 Length	34.7	0.13			0.31***	0.31***	−0.11	0.27**	−0.08
4 Intimacy	4.53	0.09		0.28***		0.40***	0.01	0.39***	−0.04
5 Own positive emotions	4.81	0.13		0.17***	0.41***		−0.60***	0.75***	−0.53***
6 Own negative emotions	2.47	0.18		−0.04	−0.18***	−0.64***		−0.42***	0.67***
7 Other's positive emotions	4.97	0.12		0.18***	0.40***	0.58***	−0.42***		−0.56***
8 Other's negative emotions	2.61	0.15		0.02	−0.11***	−0.41***	0.43***	−0.52***	

Note: Correlations above the diagonal represent between-person scores ($N = 137$). Correlations below the diagonal represent within-person scores ($n = 1158$). ICC = intraclass correlation coefficient. RMSSD = root mean square of successive differences between consecutive heart beats (measure of heart rate variability), Length = length of the interaction.

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

effect of HRV on affective interaction quality was influenced by the intimacy of the social interaction (see Table 2).[5]

To follow up on the interaction, we conducted simple slopes analyses. As shown in Figure 1, in non-intimate social interactions (mean − 1 *SD*), participants with higher HRV rated their emotions as more positive and less negative than participants with lower HRV (own positive emotions, simple slope $z = .006$ (.003), $t = 2.47$, $p = .014$, own negative emotions, simple slope $z = -.007$ (.003), $t = -2.40$, $p = .017$). This pattern was notably less pronounced in intimate social interactions (mean + 1 *SD*; own positive emotions, simple slope $z = .0002$ (.002), $t = .08$, $p = .94$, own negative emotions, simple slope $z = .001$ (.003), $t = .39$, $p = .70$).

3.2 | Other's emotions

Similarly, the linear-mixed effects model predicting other's negative emotions showed that the effect of HRV on affective interaction quality was influenced by the intimacy of the social interaction (see Table 3).[4] Again, we conducted simple slopes analyses to follow up the interaction. As shown in Figure 2, in non-intimate social interactions (mean − 1 *SD*), participants with higher HRV rated the emotions they perceived in their interaction partner as less negative than participants with lower HRV (simple slope $z = -.008$ (.003), $t = -2.60$, $p = .010$). Again, this pattern was much less pronounced in intimate social interactions (mean + 1 *SD*; simple slope $z = -.0002$ (.003), $t = -.07$, $p = .95$).

Yet, in the model predicting other's positive emotions, we did not find a significant interaction between intimacy and HRV. However, the interaction pattern still largely matched our expectations and the pattern found in the previous model predicting own positive emotions (see Table 3).

In sum, our data largely support our hypothesis. In non-intimate interactions, higher HRV predicted more positive emotions (in self) and fewer negative emotions (in self and in others).[6]

4 | DISCUSSION

The aim of the present study was to examine whether the intimacy of a social interaction influences the relationship between emotion regulation (ER) and affective interaction quality during day-to-day social interactions. For this, we combined a psychophysiological index of ER—resting heart rate variability (HRV) and an experience-sampling social interaction diary task to determine participants' affective interaction quality and perceived interaction intimacy during naturally occurring non-trivial social exchanges. We predicted higher HRV to be particularly beneficial in non-intimate interactions, which may be

[5]Note that these results could also be obtained with robust standard error estimation via clubSandwich (Pustejovsky & Tipton, 2022).

[6]Adding sex, age, latency (the interval between the time the social interaction occurred and the rating of the social interaction) and weekday (vs. weekend) as covariates to the main analyses did not change the size of the interaction effect between HRV and intimacy, even though the covariates explained additional variance in one or the other outcome measure (see Supporting Information A1, A2, B1, and B2). We also conducted additional analyses where we excluded extreme outliers (participants who did not finish the diary part of the study within 4 weeks and interactions that had been reported later than 6 h after the interaction had taken place). We found largely the same results with and without those extreme outliers (see Supporting Information C1, C2, D1, and D2).

TABLE 2 Own emotions

	Own positive emotions					Own negative emotions				
Predictors	**Estimates**	**SE**	**95% CI**	***p***	**SP R^2**	**Estimates**	**SE**	**95% CI**	***p***	**SP R^2**
Intercept	4.812	0.060	4.694 to 4.930	**<.001**		2.466	0.075	2.319 to 2.614	**<.001**	
RMSSD	0.003	0.002	−0.0001 to 0.007	.083	.005	−0.003	0.002	−0.008 to 0.002	.185	.004
Length	0.003	0.001	0.001 to 0.005	**.005**	.007					
Intimacy	0.375	0.028	0.320 to 0.430	**<.001**	.132	−0.158	0.029	−0.216 to −0.100	**<.001**	.023
RMSSD × intimacy	−0.002	0.001	−0.004 to −0.0001	**.044**	.004	0.003	0.001	0.001 to 0.005	**.013**	.005
Random effects										
σ^2	1.86					2.20				
τ_{00}	0.27_{id}					0.51_{id}				
ICC	0.13					0.19				
N	137_{id}					137_{id}				
Observations	1158					1158				
Marginal R^2/ Conditional R^2	0.172/0.278					0.032/0.215				

Note: SP R^2 = semi-partial (marginal) R^2. RMSSD = root mean square of successive differences between consecutive heart beats (measure of heart rate variability), Length = length of the interaction. ICC = intraclass correlation coefficient.

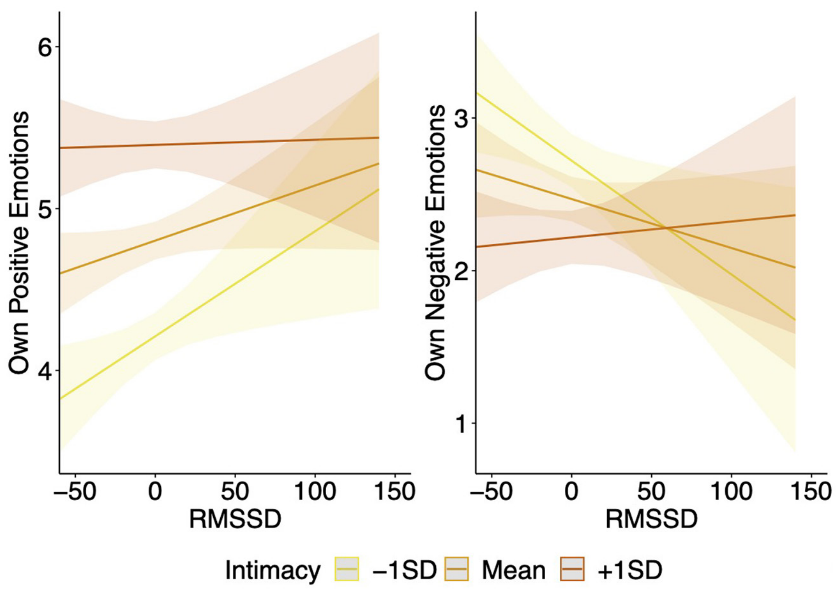

FIGURE 1 Effects plots for the models predicting own emotions for three different values of the moderating variable (mean – 1 *SD* (yellow), mean (orange), and mean + 1 *SD* (red)). Higher HRV predicts more positive and fewer negative emotions (in self) in distanced social interactions. Left panel shows the effect of HRV on positive emotions and right panel on negative emotions. RMSSD = root mean square of successive differences between consecutive heart beats (measure of heart rate variability). Error bands display 95% confidence intervals

experienced as more demanding on an individual's ER skills.

The results largely confirmed our prediction. We found that as the degree of intimacy decreased, the relationship between higher HRV and benefits for the affective interaction quality in the social interaction increased. This is in accordance with the notion that people generally feel more emotionally supported and authentic in intimate interactions (Prager, 2000), which may therefore result in less ER demand. In line with our hypothesis, in non-intimate interactions, participants with low levels of HRV experienced and perceived more negative and fewer positive emotions than participants with high levels of HRV. According to the neurovisceral integration model (Thayer & Lane, 2000), low HRV may signify a susceptibility to hyperactivity of the amygdala (Thayer et al., 2012). It is not surprising then that a non-intimate social interaction may be experienced as significantly more stressful for individuals with lower HRV compared to individuals with higher HRV.

Surprisingly, we did not find a positive association between HRV and the perceived positive emotions of the interaction partner during non-intimate interactions. There are several potential reasons that may explain the

TABLE 3 Other's emotions

	Other's positive emotions					Other's negative emotions				
Predictors	**Estimates**	**SE**	**95% CI**	***p***	**SP R^2**	**Estimates**	**SE**	**95% CI**	***p***	**SP R^2**
Intercept	4.969	0.057	4.857 to 5.081	**<.001**		2.609	0.071	2.469 to 2.748	**<.001**	
RMSSD	0.001	0.002	−0.002 to 0.005	.456	.001	−0.004	0.002	−0.008 to 0.0001	.185	.006
Length	0.003	0.001	0.001 to 0.005	**.003**	.008					
Intimacy	0.359	0.027	0.306 to 0.413	**<.001**	.130	−0.098	0.030	−0.157 to −0.039	**.001**	.009
RMSSD × intimacy	−0.001	0.001	−0.003 to −0.001	.210	.001	0.002	0.001	0.0001 to 0.005	**.028**	.004
Random effects										
σ^2	1.75					2.32				
τ_{00}	0.24_{id}					0.42_{id}				
ICC	0.12					0.15				
N	137_{id}					137_{id}				
Observations	1158					1158				
Marginal R^2/ Conditional R^2	0.167/0.268					0.018/0.168				

Note: SP R^2 = semi-partial (marginal) R^2. RMSSD = root mean square of successive differences between consecutive heart beats (measure of heart rate variability), Length = length of the interaction. ICC = intraclass correlation coefficient.

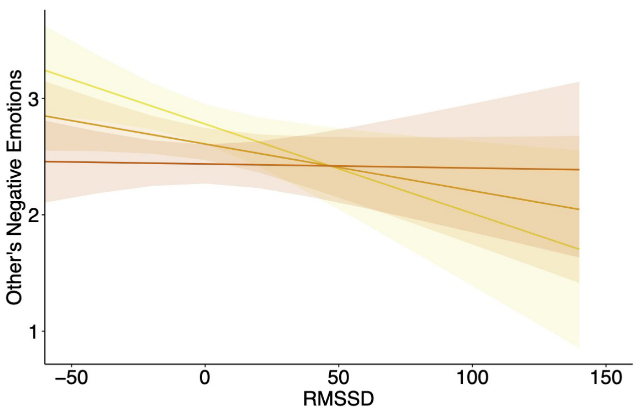

FIGURE 2 Effects plot for the model predicting other's negative emotions for three different values of the moderating (mean − 1 *SD* (yellow), mean (orange), and mean + 1 *SD* (red)). Higher HRV predicts fewer negative emotions (perceived in others) in distanced social interactions. RMSSD = root mean square of successive differences between consecutive heart beats (measure of heart rate variability). Error bands display 95% confidence intervals

lack of this effect. First, whereas intimate interactions are generally characterized by mutual acceptance and social approval (Venaglia & Lemay, 2017), non-intimate interactions may be perceived as less predictable and more taxing. This in turn may have impeded the processing of social cues and increased the likelihood of the use of mental shortcuts. Given the strong empirical evidence for the negativity bias (Baumeister et al., 2001), our participants may have been focused on the negative stimuli during non-intimate interactions and thus may have overlooked positive emotions expressed by the interaction partner, thereby limiting the variance in this measure. It is also possible that due to the intense engagement with the bothersome negative emotions that arose during non-intimate interaction and that had to be regulated urgently, the lack of positive emotions and its upregulation may not have been the focus of attention during those types of interactions reducing the influence HRV exerted on positive emotions.

Interestingly, participants with lower and higher HRV did not significantly differ in their self-reported and perceived emotions during intimate interactions. As argued above, we expected intimate interactions to be less demanding on an individual's ER ability. However, it is reasonable to assume that higher levels of HRV would nonetheless offer some benefit for the affective interaction quality even during an intimate social exchange. Yet, we did not find a relationship between interindividual differences in HRV and affective interaction quality in intimate interactions, which may be surprising given that the literature consistently points to the advantages of higher HRV for various social–emotional outcomes. It may be speculated that it is indeed the comfort of an intimate interaction that diminishes the negative outcomes usually associated with lower HRV; individuals are allowed to behave more authentically in the interaction and thus do not need to regulate their undesired or disagreeable emotions. In this way, intimate interactions may present an exception to the well-known findings that point to the importance of high levels of HRV in general. At least for the present data set, our findings highlight that the relationship between higher HRV and affective interaction quality in social interactions depends on the degree of perceived intimacy.

4.1 | Strengths and limitations

Our study offers important insights into the relationship between HRV and affective interaction quality in social interactions by highlighting the moderating effect of perceived intimacy. The present study has several notable strengths. First, utilizing a psychophysiological marker reduced subjective biases that are common for self-report measures of ER ability (Caputo, 2017; Rosenman et al., 2011). In this vein, a growing body of research supports the utility of HRV as a simple, unbiased index of ANS-driven regulated emotional responses and as an indicator of individual differences in ER ability (e.g., Appelhans & Luecken, 2006). Second, using an experience-sampling method allows to assess participants' emotions and experiences in their daily lives and, thus, provides high ecological validity (Verhagen et al., 2016). Lastly, most of the studies investigating the role of HRV in emotion expression or perception have focused on negative emotionality. However, in this study, equal attention was given to both positive and negative emotions.

Nonetheless, this research has several limitations that should be considered. The study includes only a one-time measurement of HRV and it has been found that some situational factors such as meals (Lu, 1999) and time of day (van Eekelen et al., 2004) can have an influence on HRV levels. However, resting HRV is believed to be reasonably stable, thus the single measure should be adequate (Bertsch et al., 2012). Also, only correlational support, but not causal support, was provided for the relationships among HRV and affective interaction quality. Thus, it remains unclear whether differences in HRV lead to better affective interaction quality, or whether the experience of more positive and fewer negative emotions could have an impact on HRV. Yet, the study was designed to include a temporal separation between the measures, so that participants' HRV were measured prior to collecting data on their experiences during social interactions. Further, HRV should be more stable than positive and negative affect (at least more stable than momentary or state affect—the type of affect we measured in this study) implying that the HRV should be the predictor of affective interaction quality and not vice versa. Another limitation of the present research is that social interaction quality was only measured through self-report. Although it would be interesting to investigate and compare both interaction partners' experiences during everyday social exchanges, such a study design would be challenging to realize. Lastly, the sample included mostly younger participants and a large number of participants were students. Hence, the present findings cannot readily be generalized to other populations (e.g., pensioners), as for those the relationship between HRV and affective interaction quality in non-intimate interactions may look different. Further, given that our sample was predominantly female, one could speculate that, from an evolutionary perspective, the social stress during non-intimate interactions may have had a more vital impact on stress responses in our sample than in other more mixed samples, as women should have a higher need to affiliate with others under stress to protect their offspring than men (see "tend and befriend" theory; Taylor, 2012). This, in turn, may have led to more effective ER (including vagally mediated arousal inhibition) and then more beneficial emotions in our sample than in a sample of men or both men and women. However, adding age and sex as covariates did not substantially change our effects (see Supporting Information Tables A1 and A2). Further, support seeking behaviors in response to threat exist for both women and men (Taylor, 2011) and gender differences in HRV are rather unsystematic (they depend on the specific HRV measure and on demographic variables; Umetani et al., 1998). Hence, we would expect to find similar effects of HRV on affective interaction quality in non-intimate interactions for other samples. Still, to ensure the generalizability of the findings, future studies should aim for larger and more heterogeneous samples.

5 | CONCLUSIONS

The present study provides evidence that the relationship between HRV and affective interaction quality during social interactions is moderated by intimacy such that especially in non-intimate interactions, higher HRV is more beneficial for emotional experiences. Individuals with lower HRV may not be able to respond emotionally flexibly in social exchanges, particularly in those that are perceived as non-intimate, and therefore experience those interactions as more stressful. This result is in line with findings that ER allows individuals to successfully manage stressful conditions (Thayer & Lane, 2000), whereas deficits in ER are associated with maladaptive responding, which results in prolonged negative emotionality and increases the risks of developing psychopathological conditions (Aldao et al., 2010).

Interestingly, the relationship between higher HRV and affective interaction quality was only observed during non-intimate interactions while individual differences in HRV did not seem to impact the experience and perception of emotions in intimate interaction at all. This points to the importance of considering moderating variables when investigating the associations between HRV and social–emotional outcomes. In non-intimate interactions, which may be experienced as more insecure and unpredictable and, hence, potentially more stressful, higher HRV (as an indicator of ER) resulted in more self-reported positive emotions and fewer negative emotions compared to lower HRV. While the existing literature consistently points to the benefits of higher HRV for social–emotional outcomes, our findings aid in developing a more comprehensive picture of the nature of the association between HRV and emotions in social interactions. They underline the more demanding nature of non-intimate social interactions and the adverse effects of inflexible physiological responding in such stressful situations.

In sum, this research contributes to our understanding of how characteristics of day-to-day social interactions, such as their degree of intimacy, influence the relationship between ER ability (as indexed by HRV) and emotional experiences during a social exchange. Furthermore, this study adds to the literature highlighting the utility of HRV in understanding and predicting emotional responding. As social beings, we have to navigate a variety of social interactions each day and our findings point to higher HRV as particularly beneficial for higher affective well-being in non-intimate social interactions.

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AUTHOR CONTRIBUTIONS

Heidi Mauersberger: Conceptualization; data curation; investigation; methodology; project administration; software; visualization; writing – original draft; writing – review and editing. **Jennifer L. Tune:** Data curation; formal analysis; investigation; visualization; writing – original draft. **Till Kastendieck:** Conceptualization; data curation; formal analysis; investigation; methodology; project administration; software; visualization; writing – review and editing. **Anna Z. Czarna:** Conceptualization; funding acquisition; resources; writing – review and editing. **Ursula Hess:** Conceptualization; funding acquisition; methodology; project administration; resources; supervision; writing – review and editing.

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

Appendix S1

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