Affective Science
https://doi.org/10.1007/s42761-023-00210-4

RESEARCH ARTICLE

Shared Hearts and Minds: Physiological Synchrony During Empathy

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Received: 9 December 2022 / Accepted: 19 July 2023

Abstract

Empathy is a multidimensional construct that includes changes in cognitive, affective, and physiological processes. However, the physiological processes that contribute to empathic responding have received far less empirical attention. Here, we investigated whether physiological synchrony emerged during an empathy-inducing activity in which individuals disclosed a time of suffering while their romantic partner listened and responded ($N = 111$ couples). Further, we examined the extent to which trait and state measures of cognitive and affective empathy were associated with each other and with physiological synchrony during this activity. We found evidence for physiological synchrony in skin conductance reactivity and also in interbeat interval reactivity, though only when disclosers were women, but not for respiratory sinus arrhythmia reactivity. Physiological synchrony was not consistently associated with other well-established trait and state measures of empathy. These findings identify the nuanced role of physiological synchrony in empathic responding to others' suffering.

Keywords Empathy · Physiology · Physiological synchrony · Romantic relationships

As a social species, humans show a profound capacity for empathy. Having empathy predicts a host of positive outcomes, including increased prosocial behavior (Batson et al., 1991), heightened personal and partner well-being (Morelli et al., 2015), and healthier relationships (Ulloa et al., 2017). Although people feel empathy for others in a variety of contexts, empathy may be particularly important when another person is suffering (Stellar et al., 2020). In these instances, receiving empathy can help the sufferer alleviate their negative emotions and process an unpleasant event (Carlson & Perrewè, 1999). Therefore, understanding empathy, especially in response to others' suffering, is critical to promoting healthy individuals, relationships, and societies.

Handling editor: Claudia Haase

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Empathy is a complex multidimensional construct (Hall & Schwartz, 2019). While a large body of research suggests that shared cognition and emotion are markers of empathy, far less is known about whether shared physiology contributes to empathy. We operationalized shared physiology as physiological synchrony, or the association of two or more individuals' physiologies at the same time point (Palumbo et al., 2017). Here, we aimed to document whether physiological synchrony in autonomic nervous system reactivity would emerge during an empathy-inducing situation in which one person disclosed a time of suffering while the other listened. We also examined whether physiological synchrony was associated with more cognitive (e.g., perspective-taking) and affective (e.g., emotion contagion) measures of empathy.

Empathy and Physiological Synchrony

Empathy is defined as understanding another's thoughts and feeling what they feel (de Waal, 2008). Researchers often describe empathy using more concrete processes (e.g., perspective-taking), though there is little agreement as to whether these processes constitute, contribute to, or result from the broader abstract construct of empathy (for a review, see Hall & Schwartz, 2019). More cognitive processes focus on accurately understanding the viewpoint and feelings of the other person (e.g., perspective-taking, empathic accuracy, mentalizing; Zaki,

Published online: 21 August 2023

2014). More affective processes focus on feeling the emotions of the other person (e.g., emotion contagion, personal distress, experience sharing; Preston & de Waal, 2002) and concern for the welfare of the sufferer (e.g., empathic concern, compassion; Batson et al., 2007). If empathy can be thought of as a cognitive and affective resonance between two people, it stands to reason that it may also be characterized by a physiological resonance (e.g., physiological synchrony). Despite theoretical claims about the importance of physiological synchrony to empathy (Ax, 1964, p.12), it has received little empirical attention. Building a more complete conceptualization of empathy requires a better understanding of whether physiological synchrony emerges during attempts to empathize.

Physiological synchrony is considered an interpersonal process (Helm et al., 2018; Palumbo et al., 2017) that reflects higher-level psychological processes (Danyluck & Page-Gould, 2019) and *attunement* to another person (Gates et al., 2015). There are three reasons to expect that physiological synchrony would arise during empathy-inducing situations. First, physiological synchrony supports the overarching function of empathy–coordinating individuals' behaviors (Yokozuka et al., 2018) and has been well-documented in situations requiring coordination like participating in collaborative learning sessions (Haataja et al., 2018). Second, physiological synchrony is more common in close relationships that are grounded in empathy like those between therapists and their clients (e.g., Marci et al., 2007). Third, physiological synchrony has been theoretically and empirically associated with emotion contagion (e.g., Hatfield et al., 1992; Waters et al., 2014).

In addition, the presence of physiological synchrony should be examined alongside the more traditional cognitive and affective processes that contribute to empathy to gain a deeper and more nuanced understanding of how they may be interrelated. Researchers rarely measure multiple empathic processes within the same study and there have been growing calls to include more rigorous, multifaceted measures of this construct (Hall et al., 2021). Therefore, we included trait and state measures of cognitive and affective empathy to assess the extent to which these measures correlated with each other and physiological synchrony.

Patterns and Measures of Physiological Synchrony

Although there are compelling reasons to expect physiological synchrony during empathy, it is unclear exactly what these synchronous patterns may look like. Two people may experience changes in physiological activation in the same direction (concordant synchrony). In the case of empathy, both the discloser of suffering and responder may experience increases in physiological arousal as the discloser shares their distressing experience (e.g., Levenson & Ruef, 1992). Alternatively, two people may experience changes in physiological activation in opposing directions, represented by a negative association (discordant synchrony; e.g., Di Mascio et al., 1955). In the case of empathy, the discloser may exhibit increased physiological arousal over time as they re-experience the distressing event, while the responder, from their more distanced vantage point, may feel compassion, which has been associated with reduced physiological arousal over time (Stellar et al., 2015). Although research on physiological synchrony typically focuses on concordant patterns of activity, some work has highlighted the presence and adaptiveness of discordant patterns (e.g., Gates et al., 2015). Therefore, in addition to identifying whether physiological synchrony emerges during an empathy task, we also examined whether they were best defined by concordant versus discordant patterns.

It is also unclear which physiological measures might be most likely to show synchronous patterns. To our knowledge, only three studies have examined physiological synchrony during empathy-inducing situations in which another person is seen in distress and their findings are inconsistent. Brown et al. (2021) found synchrony in pre-ejection period; Corner et al. (2019) failed to find synchrony in heart rate; and Levenson and Ruef (1992) found synchrony for some of their physiological measures, but do not discuss which measures in particular. Notably, none of these studies measured indicators of parasympathetic functioning, which scholars suggest is critical to social engagement, caretaking (Porges, 2007), and empathy for another's suffering (Stellar et al., 2015, 2020). Therefore, we also measured parasympathetic activation in our study.

Conflicting findings in past work on physiological synchrony during empathy may also be explained by different paradigms and measurement choices. Empathy has been induced by a range of paradigms including disclosure of a personal loss (Corner et al., 2019), videos and a Trier Social Stress Test (Brown et al., 2021), and pre-recorded videos of married couples trying to resolve a marital conflict (Levenson & Ruef, 1992). Physiology was sometimes measured asynchronously, rather than face-to-face (Levenson & Ruef, 1992), or calculated using lagged analyses (Brown et al., 2021). Further, empathy measures varied from compassion to empathic accuracy, were often gathered after a delay while watching (Corner et al., 2019) or rewatching (Levenson & Ruef, 1992) a video of the interaction, and sometimes collected via continuous rating dials (Levenson & Ruef, 1992). In our paradigm, we prioritized an ecologically valid empathy-inducing paradigm of disclosure of a participant-selected distressing event; measured synchronous physiology while participants were together; and collected multiple empathy measures immediately following the interaction.

Finally, we conducted this study with romantic couples given evidence that empathy may occur more readily within close relationships (Burnstein et al., 1994). We also explored whether there was an effect of the gender of the discloser on physiological patterns given evidence of gender differences in emotion disclosure and responses to receiving empathic support. Women tend to disclose more than men (Dindia & Allen, 1992) which may facilitate their partner's efforts to empathize with them and ultimately achieve synchrony. Past work has also identified gender differences in the type of support-giving (Kliewer et al., 1990), use of compassion (Salazar, 2016), and expressions of emotion contagion (Lundqvist, 1995). In sum, the present study seeks to make novel contributions to the empathy literature by exploring physiological synchrony and relating it to established measures of empathy.

Method

Participants

In this study, 111 romantic couples (222 individuals; 106 men, 109 women, 1 transgender, 2 unreported) from a large metropolitan area in Canada participated for financial compensation. Our study was sufficiently powered to detect our main interaction of interest (empathy × physiological synchrony), based on Brown et al.'s (2021) power analysis where they found 82% power to detect a similar interaction (empathy x physiological linkage) with 70 dyads (specifying a $B = 0.41$, $SE = 0.13$). Most couples were younger adults in committed non-marital relationships from diverse ethnic backgrounds (see Tables 1 and 2 for summaries of demographic information).

Procedure

Figure 1 depicts the experimental procedure. Prior to attending the laboratory, participants completed a background survey of demographic information and individual difference measures, including trait empathy (see "Measures" section). We excluded participants who had cardiovascular diseases (e.g., heart tension), used pacemakers, or were potentially pregnant, to ensure safe and clean physiological recordings.

Table 1 Means and standard deviations of demographic information

Demographics	*M*	*SD*
Age	26.76 years old	7.17
Education	3.26 (equivalent to associates, vocational, 2-year degree)	1.23
Personal income	4.13 ($20,000–$24,999)	3.23
Household income	8.32 ($50,000–$59,999)	3.38
Relationship length	4.13 years	2.67

Table 2 Frequencies of demographic information

Demographics	Frequency (%)
Sexuality	
Heterosexuals	95.49
Gay	2.70
Undeclared	1.80
Ethnicity	
European	32.51
Asian	20.69
Caribbean	6.90
South American	5.42
Middle Eastern	2.46
African	2.46
Bi- or multi-ethnic	14.29
Other	12.81
Unreported	2.46
Cohabitating	
Yes	49.55
No	48.65
Unreported	1.80
Married	
Committed Unmarried	74.77
Married	22.97
Unreported	2.25

Couples then came into the laboratory together for a 2-h study session, which was video recorded. Participants were each connected to the MP150 data acquisition and analysis system (BIOPAC Systems). All measures were sampled at 1 kHz with a low-pass filter of 8 Hz and a high-pass filter of 4 Hz to reduce high- and low-frequency noise during the data collection phase. We collected electrocardiography (ECG) by placing two sensors below the lowest rib of the right and left sides of the torso. We recorded respiration by placing a band across the upper torso with the same sampling rate and filters as ECG. We collected skin conductance levels (SCL; measured in microSiemens, μS) by placing two sensors on the surface of participants' palms. Overall, we followed standard practice when collecting physiology data (e.g., Danyluck & Page-Gould, 2019; Helm et al., 2014).

Couples then participated in a variety of tasks including discussing a negative event that caused them suffering.[1] Baseline physiology measures were collected 15 to 20 minutes into

[1] Participants also took part in other tasks (reading to each other, discussing something they wanted their partner to change, and expressing gratitude towards each other) collected to answer unrelated research questions.

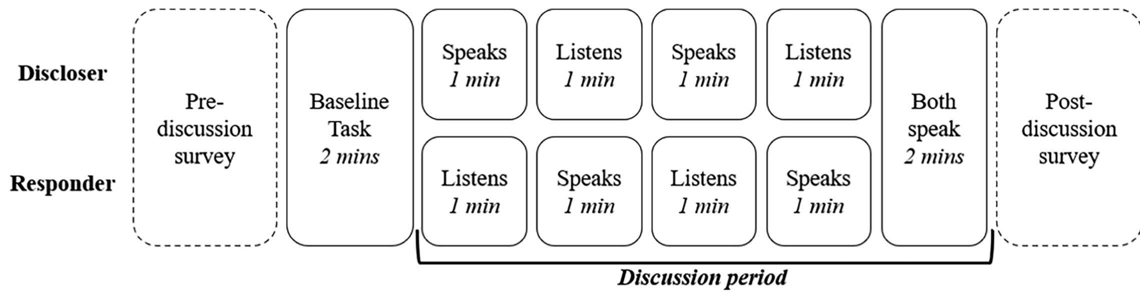

Fig. 1 Overview of experimental procedure

the session for 2 minutes immediately prior to the discussion. For the baseline task, participants sat in the same room with their eyes closed and breathed normally. Then participants discussed, "a negative event in [their] life that caused [them] the most suffering and continues to affect or impact [them]." They were asked to, "discuss an event that [was] not related to [their] partner or [their] relationship with [their] partner," to reduce the tendency for other emotions like anger or shame to arise, which might be the case if partners were the cause of the negative event. These instructions were adapted from prior research (Fritz et al., 2003). Examples of the topics discussed included conflicts with their parents, the death of a loved one, or adjusting to life in Canada after immigrating.

One member of each dyad was randomly assigned to share their negative event first (discloser), while the other person listened (responder). Disclosers were given 1 minute to share the experience, while the responder was told not to ask questions or interrupt. After the first minute, the responder was assigned 1 minute to respond to their partner's experience while the discloser listened. The discloser then spoke again for 1 min, uninterrupted, followed by the responder for 1 min, uninterrupted. Then, both participants talked freely for 2 minutes. As a result, the discussion included 4 minutes in which only one person spoke, and 2 minutes with a free back-and-forth, for a total of 6 minutes. This structure ensured each participant was given an equal amount of time to speak. During pilot-testing, participants noted that the conversation felt natural, which speaks to the generalizability of our results.

After the discussion, each participant reported how much they felt, and how much they thought that their partner felt, a variety of emotions (see measures). Couples then reversed roles so the other participant could disclose a negative event in the same format as the earlier conversation, and then filled out the same measures. At the end of the final discussion, the physiology recording equipment was removed and participants were debriefed.[2]

[2] After the laboratory session, couples filled out other measures unrelated to the current project, including a daily-diary study and a follow-up survey.

Measures

Bivariate correlations among all study variables are shown in Supplemental Table S1.

Responder's Trait Empathy

Trait empathy was collected using the Interpersonal Reactivity Index (IRI), a 28-item questionnaire in which participants reported how much each statement described them from 1 (*does not describe me well*) to 6 (*describes me well*; Davis, 1983). This questionnaire assesses different facets of empathy using four subscales. We focused on three subscales. As a trait measure of cognitive empathy, we used the perspective-taking subscale (e.g., "When I'm upset at someone, I usually try to 'put myself in his shoes' for a while"; $M = 4.01$, $SD = 0.86$; $\alpha = .79$). As a trait measure of affective empathy, we used the personal distress subscale (e.g., "I sometimes feel helpless when I am in the middle of a very emotional situation"; $M = 2.81$, $SD = 0.87$; $\alpha = .79$). The personal distress subscale was used as a measure of affect contagion, given that it assesses aversive arousal that one experiences in response to another person's suffering (Stosic et al., 2022). Finally, as a trait measure of empathic concern, we used the empathic concern subscale (e.g., "I often have tender, concerned feelings for people less fortunate than me"; $M = 4.14$, $SD = 0.87$; $\alpha = .73$).

Responder's State Empathy

After each discussion, participants reported how much they were feeling a variety of emotions (discloser-reported emotions: sad, upset, down, anxious, stressed, nervous, angry, embarrassed, and grateful; responder-reported emotions: sad, upset, down, anxious, stressed, nervous, compassion, sympathy, moved, soft, angry, embarrassed, and grateful) from 1 (*not at all*) to 10 (*as much as I've ever felt*). Participants also reported on how much they perceived their partner to experience each of the emotions (e.g., disclosers reported on how much the listener felt compassion) from 1 (*not at all*) to 10 (*as much as they've ever felt*).

Empathic Accuracy As a state measure of cognitive empathy, we assessed empathic accuracy using past correlational approaches (e.g., Zaki et al., 2008). Specifically, for the nine emotions we collected from disclosers, we calculated the overall association between disclosers' reports of their own emotions and responders' estimates of the disclosers' emotions.

Emotion Contagion We calculated emotion contagion similarly to empathic accuracy. Across the same nine emotions, we assessed the overall association between disclosers' reports of their own emotions, but this time with responders' reports of their own emotions.

Compassion As state measure of the responder's empathic concern, we aggregated responders' ratings of the following feelings: compassion, sympathy, moved, and soft ($M = 6.15$, $SD = 2.46$; $\alpha = .90$).

Processing of Physiology Signals

After data collection, ECG artifacts in the form of R-spikes were visually identified over the 2-minute baseline and 6-minute discussion periods; they were manually corrected by trained research assistants. Files requiring manual corrections for 5% (or more) of the data were removed from analyses, which is in keeping with previous studies of physiology (Stellar et al., 2014, 2015). We chose to perform manual corrections due to evidence that respiratory sinus arrhythmia (RSA) estimates are highly sensitive to errors in heartbeat intervals (Berntson & Stowell, 1998). This method of corrections is also more accurate in comparison to programmed corrections. From the cleaned ECG channel, trained research assistants used BIOPAC's analysis system to generate a continuous output of the time between RR intervals of heart beats, or interbeat interval (IBI; measured in seconds, s). RSA (measured in milliseconds, ms) was calculated using BIOPAC, which uses the peak-to-trough method to find the average time between R-spikes in the ECG signal during a participant's inhalation versus exhalation using their own respiration channel (Grossman et al., 1990). This produced a continuous time-series output for RSA; we did not log transform, as is often the case with measures of RSA, because our data were already normally distributed.

A trained research assistant then extracted the data from BIOPAC, producing mean IBI and SCL values for each 5-second epoch, and mean RSA values for each 30-second epoch. These window sizes were selected to sufficiently capture variance in physiological responsivity, based on prior research (Danyluck & Page-Gould, 2019; Helm et al., 2014, 2018; Tschacher & Meier, 2019). Notably, longer epochs are necessary for RSA because it is derived from respiration, a slower physiological signal, where breaths per minute typically range from 9 to 25. Therefore, we chose an epoch size for RSA of 30 seconds because this allowed for multiple inhalation and exhalations to occur and it was the minimum time used in past work on synchrony for RSA (Danyluck & Page-Gould, 2019; Gates et al., 2015; Helm et al., 2014).

A final cleaning stage involved identifying data points that were unusually high, falling outside of the normative physiological range (IBI between 0.3 and 1.5 s, SCL between 1 and 20 μS; RSA between 40 and 400 ms; de Geus et al., 1995; Grossman et al., 1991; Kollai & Mizsei, 1990) through visual inspection of histograms plotting all mean values over time for each participant. Individuals with over 30% of baseline or non-baseline values falling outside of physiological range were removed from the analyses. As a result, sixteen participants were removed because their baseline or non-baseline physiology was inconsistent with these inclusion parameters.[3] If one dyad member's physiology was removed, physiological synchrony could not be assessed in the couple and was not analyzed. This resulted in a final sample of ninety-five couples ($N = 190$ participants).

For all analyses, we used physiological reactivity measures that were created by subtracting the individual's final baseline epoch (i.e., at the end of the baseline activity) from each epoch during the discussion period; this also served to center the physiology measure at the person level. Each measure of empathy was grand-mean centered. All analyses were conducted in IBM SPSS Statistics 28 (IBM Corp., 2021).

Coding Events

As a check for whether the topics discussed were distressing, we had a team of three trained coders rate the severity and stressfulness of the events that were disclosed by participants from 1 (*not at all severe/stressful*) to 3 (*very severe/stressful*). Coders showed a reliability of ICC (two-way, random) of 0.64. On average, the topics discussed were somewhat severe ($M = 1.96$, $SD = 0.46$).

Results

Physiological Levels for Disclosers and Responders

We wanted to first gain a better understanding of how the empathy task impacted the physiological levels of disclosers and responders. Therefore, we examined whether disclosers and responders' IBI, RSA, and SCL levels increased or decreased from the baseline to the empathy activity using a paired samples t-test (see Fig. 2 for individual means

[3] One participant did not complete the background survey and four did not complete the lab survey—these participants were retained to study physiology.

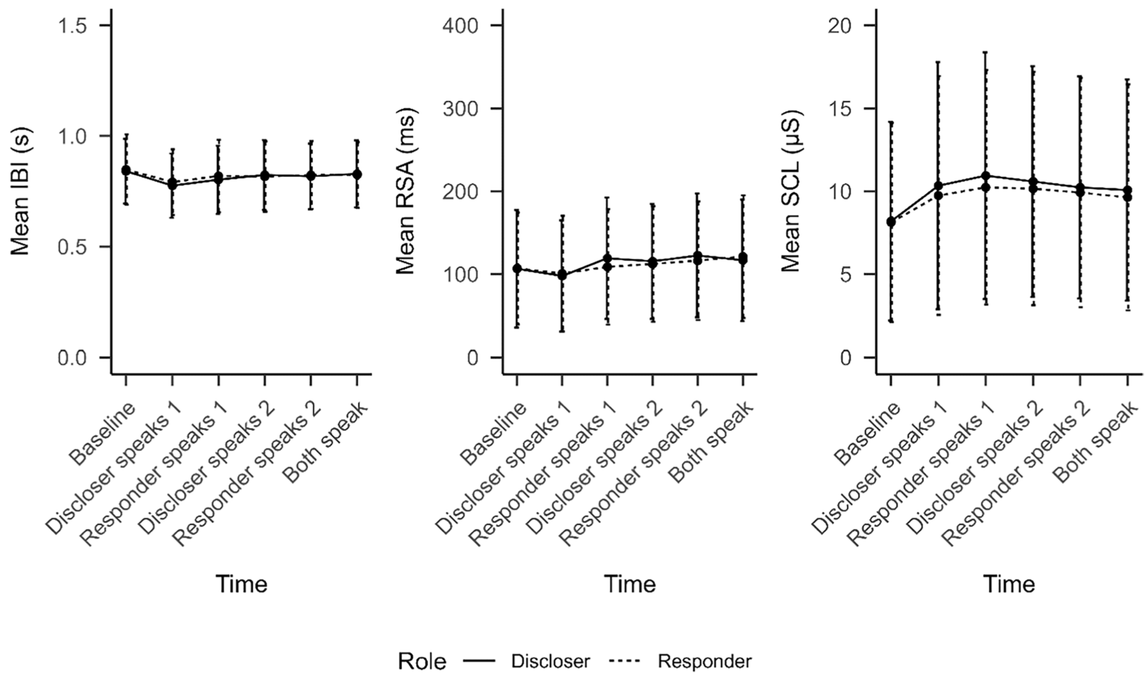

Fig. 2 Mean IBI (left), RSA (middle), and SCL (right) for disclosers and responders across the baseline and different parts of the empathy activity. Error bars represent standard deviations at each point in the task. Baseline and "both speak" segments aggregate physiological measures across 2 minutes; all other segments aggregate physiological measures across 1 minutes

and standard deviations for each minute of the task for disclosers and responders). We found that, on average, disclosers' ($M = -0.02$, $SD = 0.09$, 95% CI [$-0.04, -0.02$], $t(186) = -4.45$, $p < .001$) and responders' ($M = -0.03$, $SD = 0.09$, 95% CI [$-0.04, -0.02$], $t(186) = -5.09$, $p < .001$) IBI decreased during the empathic activity compared to the baseline. On the other hand, disclosers' ($M = 9.76$, $SD = 58.71$, 95% CI [0.84, 18.67], $t(168) = 2.16$, $p = .02$) and responders' ($M = 7.59$, $SD = 57.53$, 95% CI [4.43, -1.15], $t(168) = 1.72$, $p = .04$) RSA increased during the empathic activity compared to the baseline. Similarly, we found that disclosers' ($M = 2.17$, $SD = 2.91$, 95% CI [1.75, 2.59], $t(186) = 10.21$, $p < .001$) and responders' ($M = 1.76$, $SD = 2.43$, 95% CI [1.41, 2.11], $t(187) = 9.94$, $p < .001$) SCL increased during the empathic activity compared to the baseline. These findings suggest this task elicited activation of both the parasympathetic (i.e., RSA) and sympathetic (i.e., SCL) nervous systems for both disclosers and responders.

In addition, we wanted context for any potential synchrony findings, which only identify if there is an association between two peoples' physiologies, but not whether shared physiological activation is increasing or decreasing together over the course of the empathy task. To this end, we examined how participants' IBI, RSA, and SCL reactivities changed over the course of the empathy task for disclosers and responders. To account for dyadic interdependencies in the data, we estimated linear growth curve models in which changes in physiology were predicted by time across partner roles (discloser or responder) and conversations (giving us a three-way interaction of time × role × conversation). We nested physiology within conversations within time, specifying a univariate covariate matrix. We included random effects of both discloser and responder roles, as well as the interaction of these roles with time, again specifying a univariate covariance matrix. We coded time such that the first time point in the conversation was coded as 0, and all subsequent time points were coded in 1-point increments.

Our three-way interaction between time, role, and conversation was not significant for IBI ($B = 0.00$, $SE = 0.00$, 95% CI [0.00, 0.00], $t(2621.78) = -0.86$, $p = .39$; note this model did not converge), RSA ($B = 1.56$, $SE = 1.10$, 95% CI [-0.60, 3.71], $t(317.20) = 1.42$, $p = .16$), or SCL ($B = -0.01$, $SE = 0.01$, 95% CI [-0.04, 0.01], $t(185.70) = -1.02$, $p = .31$) reactivity over time. Next, we looked at the 2-way interaction between time and role to examine whether there were different patterns across time for the discloser and responder roles independent of conversation. Again, we found no effects for IBI ($B = 0.00$, $SE = 0.00$, 95% CI [0.00, 0.00], $t(23.38) = -5.78$, $p < .001$), RSA ($B = 0.05$, $SE = 0.47$, 95% CI [-0.87, 0.97], $t(176.59) = 0.11$, $p = .92$), or SCL ($B = 0.00$, $SE = 0.01$, 95% CI [-0.01, 0.02], $t(186.25) = 0.62$, $p = .53$). Finally, we looked at whether there was an effect of time, and found no effect for IBI ($B = 0.00$, $SE = 0.00$, 95% CI [0.00, 0.00], $t(118.0.47) = 8.64$,

$p < .001$), but did find an effect of time for RSA ($B = 1.01$, $SE = 0.22$, 95% CI [0.57, 1.46], $t(152.68) = 4.53$, $p < .001$) and SCL ($B = -0.01$, $SE = 0.00$, 95% CI [−0.01, 0.00], $t(186.86) = -2.77$, $p = .01$). In sum, we found there was no effect of role on changes in physiology over time but did find that RSA increased over time, while SCL decreased.

Physiological Synchrony

There are numerous methods for computing physiological synchrony, including examining concurrent trends, correlations, and bivariate lagged modelling of partners' physiologies (Helm et al., 2018). However, these methods are limited by their inability to differentiate between whether synchrony arises due to a common trend, a common fluctuation around a trend, or both. To overcome these limitations and account for violations of the assumption of independence due to the repeated nature of the data, we used a non-directional concurrent synchrony method described by Helm et al. (2018), implemented via a mixed model analysis (Kenny et al., 2006).

We estimated dyadic models in which the responder's physiology was predicted by the discloser's physiology across time, but the non-directional concurrent synchrony analyses provide identical results regardless of which partner's physiology is the predictor and which is the outcome (Helm et al., 2018; see supplemental Table S2 for results from models predicting discloser physiology from responder physiology). Again, we coded time such that the first time point in the conversation was coded as 0, and all subsequent time points were coded in 1-point increments. Also following recommendations for non-directional concurrent synchrony by Helm et al. (2018), we removed both linear and quadratic effects of time from our physiology measures, removing common trends based on time (i.e., common environmental influences), then standardized them within conversation to allow for the estimation of the correlation between partners, rather than directional predictions.

We used a 2-level multilevel model such that participants' physiological responses (level 1) were nested within couples (level 2) crossed with conversation. In keeping with past recommendations on dyadic analytical approaches (Bolger & Laurenceau, 2013; Dwyer, 1983; Kenny et al., 2006), a first-order autoregressive covariance matrix was specified for the residual variance covariance matrix to account for the serial correlation of the physiological time-series data. We specified the random effects variance covariance matrix as a two-intercept model, with separate random effects for each conversation, and an unstructured matrix to allow for estimation of heterogeneous variances and covariances within and across conversations. We estimated random slopes for each conversation, and all models were estimated using Satterthwaite degrees of freedom. We did not model random intercepts because they had little variance and created convergence issues.We accounted for the effect of disclosers' genders by including it as a binary variable in our model (effect coded as 0.5 for men and 1.5 for women). We found evidence of concordant patterns of synchrony for SCL reactivity ($B = 0.12$, $SE = 0.02$, 95% CI [0.09, 0.16], $t(85.70) = 7.74$, $p < .001$), but no synchrony for IBI ($B = 0.01$, $SE = 0.01$, 95% CI [−0.02, 0.03], $t(85.42) = -0.72$, $p = .47$) or RSA ($B = -0.03$, $SE = 0.03$, 95% CI [−0.09, 0.04], $t(81.20) = -0.82$, $p = .42$) reactivity.[4]

Given the importance of gender, we examined the association between responders' and disclosers' physiologies when either the man or woman was the discloser[5] (e.g., discloser RSA reactivity × gender of discloser). We found an effect of disclosers' gender on IBI reactivity ($B = 0.05$, $SE = 0.02$, 95% CI [0.01, 0.10], $t(91.56) = 2.21$, $p = .03$; Fig. 3). To further probe this finding, we examined the association between disclosers and responders' IBI reactivities while separating the model based on the gender of the discloser. We found evidence that when disclosers were women, there was a positive association between discloser and responder IBI reactivity ($B = 0.05$, $SE = 0.02$, 95% CI [0.01, 0.09], $t(89.12) = 2.25$, $p = .03$), but no evidence of synchrony of IBI reactivity when disclosers were men ($B = -0.01$, $SE = 0.01$, 95% CI [−0.03, 0.02], $t(83.90) = -0.39$, $p = .70$). Disclosers' gender did not have an effect on RSA ($B = 0.08$, $SE = 0.06$, 95% CI [−0.04, 0.19], $t(82.86) = 1.34$, $p = .18$) or SCL ($B = 0.00$, $SE = 0.03$, 95% CI [−0.06, 0.05], $t(80.60) = -0.08$, $p = .94$) synchrony. To summarize, there was evidence of concordant patterns of SCL reactivity and IBI reactivity, although the latter was only the case when disclosers were women.

Physiological Synchrony and Measures of Responder's Cognitive and Affective Empathy

Before examining any relationships between synchrony and measures of cognitive and affective empathy, we first wanted to test how much these cognitive and affective measures related to each other. For example, how much did a responder's state perspective-taking (i.e., empathic accuracy) correlate with their state compassion (i.e., reports of compassion) within each person? We computed

[4] To allow for more direct comparison of IBI and SCL with RSA, we examined synchrony when IBI ($B = 0.00$, $SE = 0.03$, 95% CI [−0.06, 0.05], $t(2230) = -0.15$, $p = .88$) and SCL ($B = 0.10$, $SE = 0.04$, 95% CI [0.04, 0.17], $t(2170) = 2.99$, $p < .01$) were binned at 30 s and found consistent results. We also created 60-s bins for RSA, for readers concerned about our 30-s RSA bins, and found consistent results ($B = -0.05$, $SE = 0.07$, 95% CI [−0.19, 0.08], $t(52.69) = -0.78$, $p = .44$).

[5] Gay couples ($N = 2$) were randomly assigned roles as man or woman. To ensure their assignment had no effect, we replicated the results when switching the assigned gender roles and excluding gay couples (see Supplemental Table S3).

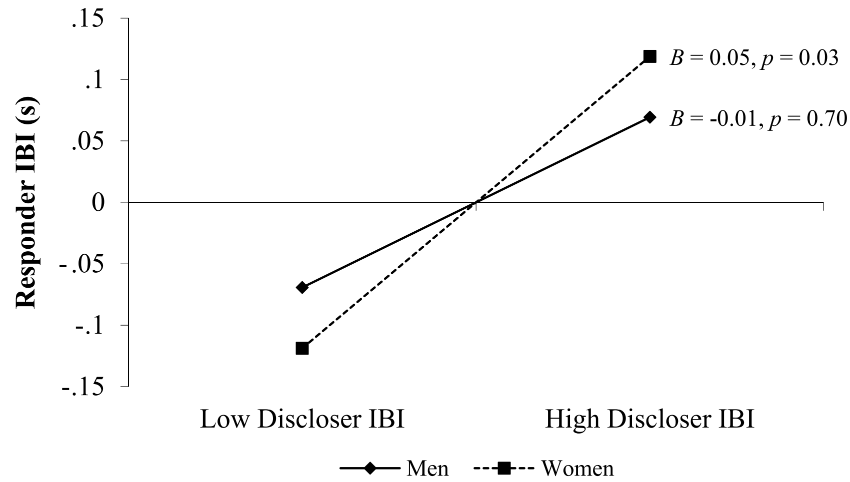

Fig. 3 Plot predicting responder IBI reactivity from discloser IBI reactivity for conversations where disclosers were men or women

Pearson correlations for responders, in line with past studies that recommend within-person correlation testing for analyzing distinguishable dyadic data (Gonzalez & Griffin, 1999). We found that responders' state measures were moderately correlated with each other though sometimes, unexpectedly, these correlations were negative (e.g., responder compassion and empathic accuracy; see Table 3). Trait measures were generally not correlated with each other or with state measures (except empathic concern and perspective-taking, which were moderately associated; see Table 3).

Next, we examined how physiological synchrony was associated with these measures of responders' cognitive and affective empathy (see Supplement Table S4:6 for two-way interactions with discloser-reported and three-way interactions with discloser- and responder-reported empathy measures). We employed the same model we used to test the presence of physiological synchrony, but included two-way interactions testing the extent to which responder-reported empathy measures moderated the effect of discloser physiology in predicting the responder's physiology (e.g., responder trait perspective-taking × discloser physiology). We ran separate models for each empathy measure. All continuous variables were grand-mean centered. We used the same two-intercept approach to model random effects separately by conversation, modelling all variances and covariances within and between conversation. Simple effects were examined using Aiken and West's (1991) test of simple slopes only when significant interactions were detected. We included an alpha correction for running multiple tests by dividing alpha ($p = 0.05$) by six for the number of trait and state measures of empathy we tested for each of our physiology measures; as such, effects were interpreted as significant for $p < 0.008$ (see Supplement Table S7:9 for three-way interactions with gender).

Cognitive Empathy

Responder trait perspective-taking was not related to synchrony in IBI ($B = 0.00$, $SE = .01$, 95% CI [−.03, .03], $t(126.09) = .03$, $p = .98$), RSA ($B = -0.04$, $SE = 0.03$ 95% CI [−0.10, 0.03], $t(140.02) = -1.06$, $p = .29$), or SCL ($B = 0.02$, $SE = 0.02$, 95% CI [−0.02, 0.05], $t(133.49) = 1.04$, $p = .30$). Responder state empathic accuracy was not related to synchrony for IBI ($B = -0.02$, $SE = 0.04$, 95% CI [−0.09, 0.06], $t(135.97) = -0.50$, $p = .62$), RSA ($B = 0.01$, $SE = 0.10$, 95% CI

Table 3 Within-person associations between responders' measures of empathy

	Trait measures			State measures		
	1	2	3	4	5	6
Trait measures						
1. Perspective-taking	–	−.13	**.55**	−.02	.01	.06
2. Personal distress		–	.08	.04	.02	.04
3. Empathic concern			–	.01	.01	.02
State measures						
4. Empathic accuracy				–	**.55**	**−.41**
5. Emotion contagion					–	**−.31**
6. Compassion						–

Bolded values are significant at $p < .05$

[−0.20, 0.22], $t(127.16)=0.10$, $p=.93$), or SCL ($B=$-0.06, $SE=0.05$, 95% CI [-0.16, 0.04], $t(134.60)=-1.16$, $p=.25$).[6]

Affective Empathy

Responder trait personal distress was not related to synchrony for IBI ($B=-0.01$, $SE=0.01$, 95% CI [−0.04, 0.01], $t(125.02)=-1.11$, $p=.27$), RSA ($B=-0.06$, $SE=0.04$, 95% CI [−0.13, 0.01], $t(131.16)=-1.62$, $p=.11$), or SCL ($B=0.02$, $SE=0.02$, 95% CI [−0.02, 0.05], $t(119.44)=1.02$, $p=.31$). State emotion contagion was also not related to synchrony for IBI ($B=0.02$, $SE=0.03$, 95% CI [−0.03, 0.08], $t(129.65)=0.75$, $p=0.45$), RSA ($B=-0.06$, $SE=0.08$, 95% CI [−0.22, 0.10], $t(134.27)=-0.75$, $p=.45$), or SCL ($B=-0.02$, $SE=0.04$, 95% CI [−0.09, 0.05], $t(141.37)=-0.53$, $p=.60$).

Empathic Concern

Responder trait empathic concern was not related to synchrony for IBI ($B=0.00$, $SE=0.01$, 95% CI [−0.03, 0.02], $t(126.34)=-0.13$, $p=.90$), RSA ($B=-0.04$, $SE=0.03$, 95% CI [−0.10, 0.03], $t(146.82)=-1.10$, $p=.27$), or SCL ($B=0.00$, $SE=0.02$, 95% CI [−0.03, 0.04], $t(134.75)=.20$, $p=.84$). Responder's reports of compassion was also not related to synchrony for IBI ($B=-.01$, $SE=.00$, 95% CI [−.02, .00], $t(134.70)=-1.39$, $p=.17$), RSA ($B=0.01$, $SE=0.01$, 95% CI [−0.01, 0.04], $t(139.17)=1.00$, $p=.32$), or SCL ($B=0.00$, $SE=0.01$, 95% CI [−0.01, 0.01], $t(146.99)=-0.34$, $p=.74$).

Discussion

During a task designed to induce empathy, we detected concordance of IBI and SCL reactivities, though the former was only the case when women disclosed their suffering. These results build on the synchrony literature and offer initial support that physiological synchrony of certain measures may contribute to the broader construct of empathy. Our study also supports the merit of considering the effect of gender in studies of physiological synchrony, which may be related to the different ways in which men and women experience and express empathy (Christov-Moore et al., 2014). Although contrary to our hypothesis, the lack of synchrony for RSA falls in line with studies that find greater RSA synchrony may occur during relaxing passive, rather than emotionally active, tasks (Waters et al., 2017). It also may be a consequence of the fact that RSA measurement while a person is talking may be less likely to accurately reflect actual parasympathetic activity (Grossman et al., 1991). These findings support claims that physiological synchrony deserves greater representation in definitions of empathy as it does emerge, albeit in a nuanced way, during empathy-inducing tasks.

We found no robust associations between cognitive and affective measures of a responder's trait or state empathy and physiological synchrony. The absence of such an association is consistent with other studies (Brown et al., 2021). It may also reflect a broader tendency for physiological measures to show low correlations with self-reported measures, even reported measures of emotion (Mauss et al., 2005). It also supports concerns about the face validity of established measures of empathy (Hall & Schwartz, 2019) and past failure to find convergence between self-report and performance-based measures of empathy (Murphy & Lilienfeld, 2019). Our findings speak to growing concern regarding how to conceptualize the broader construct of empathy and may support the need to bypass the general term for empathy for more specific constructs (e.g., perspective-taking).

There are some limitations to this work. First, we focused on the effects of empathy on physiological synchrony between romantic partners, but the patterns of these effects may differ in other types of close relationships (e.g., among friends) or between strangers. Second, there is the potential that physiological synchrony did not necessarily emerge because of empathy, but rather as a consequence of engaging in a shared activity. Third, our measures of empathy were less granular than previous studies that have obtained more complex measures of emotions by having participants watch, or rewatch, their interaction with a rating dial to continuously measure emotions (e.g., Levenson & Ruef, 1992). Fourth, the length of our baseline task was shorter than the typical 5 to 10 minutes that some have recommended to allow participants to adjust to wearing physiology equipment (e.g., Jennings et al., 1992), though our baseline did occur 20 minutes after participants were connected to the equipment, hopefully providing participants ample time to get used to wearing it and for physiology levels to reach typical baseline before the conversation.

In conclusion, our results highlight the importance of studying physiological synchrony during empathy and offers important insights into the complexities of conceptualizing and measuring the important, but broad, construct of empathy.

Additional Information

Funding This work was supported by the Social Sciences and Humanities Research Council (#503200) and Canada Foundation for Innovation (#502426).

Conflicts of Interest The authors declare no competing interests.

Availability of Data and Material Data and materials for this study can be accessed at https://osf.io/ka6mq/.

[6] Testing these models using alternate difference-score measures of empathic accuracy and emotion contagion showed the same results, as did dividing these measures into positive and negative emotions (see Supplemental Tables S10:11).

Code Availability The code for this study can be accessed at https://osf.io/ka6mq/.

Authors' Contributions BML, EAI, JES, contributed to the study design and data collection. JES formulated the initial research question. AG provided critical inputs on data analyses. JQ analyzed the data, interpreted the results, and drafted the manuscript. All authors provided critical revisions and approved the final version of the manuscript for submission.

Ethics Approval All procedures comply with ethical regulations and were approved by the University of Toronto Office for Research Ethics.

Informed Consent Informed consent was received from all participants prior to conducting the study.

Consent for Publication Not applicable.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s42761-023-00210-4.

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