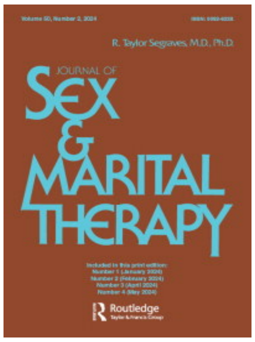

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RESEARCH ARTICLE

Physiological Synchrony During Partnered Sexual Activity

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ABSTRACT
Physiological synchrony (PS) refers to the coordination of bodily responses in close relationships. It seems to be linked to relational well-being, satisfaction, closeness, and empathy. Recent research extends these findings to sexual relationships as well, with evidence suggesting that PS may predict attraction and sexual satisfaction. The current study focuses on PS during sexual activity within established couples. Results suggest that PS develops during sexual activity, in certain contexts, and tends to be greater in magnitude during sexual encounters than during non-sexual interactions. Results may shed light on the dyadic psychophysiological factors relevant to sexual experiences.

Physiological synchrony (PS) is a phenomenon characterized by interpersonal covariation across a range of biological signals with implications for the degree of connectivity present in a social exchange (for a review, see Palumbo et al., 2017). Research has consistently shown that (1) synchrony reliably manifests in social contexts (e.g., Mayo, Lavidor, & Gordon, 2021), (2) higher levels of synchrony tend to arise between individuals with closer or more intimate relationships (e.g., Konvalinka et al., 2011), and (3) levels of synchrony are often linked to associated relational processes, including relationship satisfaction and distress (e.g., Helm et al., 2014). Given that sexuality is inherently dependent on cues from both our social and biological environments, it stands to reason that patterns of physiological exchange between romantic partners may be relevant to the quality of their sexual relationships. Despite this, very little research has taken a dyadic psychophysiological approach to studying sexual relationships and, to that end, the role of PS in sexuality remains opaque.

PS was first studied in the context of development psychobiology, with researchers finding that infants and their primary caregivers show remarkably similar patterns of physiological responding over time (for a review see Feldman, 2007). These coregulatory patterns are crucial for human development, providing the scaffolding for infants to attune to their social environment and regulate their nervous system around a stable, homeostatic setpoint (Feldman, 2007). More recent research has extended these findings across the lifespan, demonstrating that adults reliably incorporate subtle cues from important relationships into their own psychobiological system (Beckes & Coan, 2011; Butner, Diamond, & Hicks, 2007; Helm et al., 2014; Schoebi, 2008). In terms of PS and adult relationships, the majority of research to-date has focused on romantic relationships. It seems that the intimacy associated with such relationships confers a greater tendency to physiologically synchronize and to do so with a greater magnitude than is typically observed in other kinds of relationships (for a review, see Palumbo et al., 2017).

While researchers have examined PS across a wide range of relational contexts, few studies have focused on physiological covariation in sexual relationships. This gap is notable, given that

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physiological covariation is relevant to relationship dynamics which, in turn, impact overall levels of sexual well-being (Fisher et al., 2015; Timmons, Margolin, & Saxbe, 2015). Moreover, the autonomic nervous system plays an important role in overall sexual function (e.g., Meston, 2000; Meston & Stanton, 2019; Stanton et al., 2015), and physiological coregulation could theoretically impact sexual experiences by way of dyadic autonomic modulation (i.e., helping to maintain ideal levels of autonomic arousal across a sexual experience). Finally, there's evidence that synchrony is relevant to sexual satisfaction (Freihart & Meston, 2019; Prochazkova, Sjak-Shie, Behrens, Lindh, & Kret, 2022) and may even facilitate the ability to respond to partner affective cues, a quality that is certainly relevant for sexual experiences (Timmons et al., 2015). Despite this, virtually no contemporary research has taken a dyadic psychophysiological approach to studying sexual relationships. Indeed, since Masters and Johnson's seminal work in the 1960s (Masters et al., 1966), the only studies to dyadically measure physiology during sex have largely done so to examine the safety of autonomic arousal levels (for a review, see Falk, 2001). No dyadic psychophysiological studies have looked at the *relationship* between partner's physiological signals during sex, and as a result, nothing is yet known about the way sexual partners respond to each other autonomically during sexual activity.

The current study aims to address this gap and, in doing so, deepen our understanding of interpersonal autonomic synchrony and its role in sexual behavior. To that end, PS will be measured in an ecologically valid, naturalistic setting: at home, during partnered sexual activity. We hypothesize that statistically significant PS will arise during sexual activity and that the magnitude of synchrony observed will be stronger during sexual activity than during a baseline task or non-sexual interactions. A secondary, exploratory aim includes determining whether a concurrent or lagged PS model best fit the data. Concurrent synchrony implies a moment-to-moment coherence of physiological signals in a bidirectional, reciprocal fashion (e.g., the simultaneous fluctuation of spousal HRs over time). Lagged synchrony, on the other hand, is characterized by regulating or attuning *to* a partner, or demonstrating similar physiological changes but at a slightly later point in time (e.g., parent HRV at time point 1 predicting infant HRV at time point 2) (Helm et al., 2014). Concurrent and lagged models reflect conceptually different forms of synchrony: synchrony in which two people covary concurrently tends to be more situational and less relational, whereas lagged synchrony tends to reflect patterns of attunement (Helm, Miller, Kahle, Troxel, & Hastings, 2018). As no studies, to date, have examined PS during sexual activity, we do not have an priori hypothesis for this more exploratory study aim. It is our hope that these results will illuminate the degree to which autonomic activation during sexual activity is influenced by partner cues.

Materials and methods

Participants

Participants were 116 adults (58 total dyads) who had currently been in heterosexual, monogamous sexual relationships for at least 6 months. Recruitment took place through online advertisements on platforms such as Facebook, Reddit, and Craigslist, as well as through fliers posted throughout the local community. Interested participants called the laboratory for a phone eligibility screening. Both members of each couple were required to call the laboratory separately in order to confirm eligibility while maintaining individual confidentiality.

Inclusion criteria included being: between the ages of 18-55, fluent in English, and sexually active with their partner within the past four weeks. Exclusion criteria included: current usage of beta blockers, antidepressants, anxiolytics, antipsychotics, estrogens, androgens, or any medical treatments to enhance sexual response; presence of cardiac conditions or a history of an adverse cardiac event; history of major pelvic surgery; being peri- or post-menopausal; currently pregnant or breastfeeding; reporting a current diagnosis of a sexually transmitted infection; being legally blind and/or deaf; reporting an Autism Spectrum Disorder diagnosis; and having preexisting concerns that prevent their ability to engage in penetrative sex (e.g., sexual pain, erectile dysfunction).

Participants were instructed not to engage in alcohol and/or recreational drug use during data collection, as such substances can change patterns of autonomic reactivity and sexual arousal. To that end, participants who reported "always" or "almost always" engaging in sex while using such substances were excluded from participation (Gardner & Mouton, 2015; Peugh & Belenko, 2001).

A total of 522 individuals contacted the laboratory to express interest in the study. Of those, 434 (83.14%) completed a phone screen to assess eligibility. Two hundred and seventy participants met the study inclusion/exclusion criteria; 228 (i.e., 114 couples) formally enrolled in the study. Once enrolled, 45 couples dropped out or became unresponsive and an additional 11 couples had unacceptable levels of noise in their physiological data and were thus excluded from analysis, leaving a final analytic sample of 116 individuals or 58 couples.

The final analytic sample was primarily comprised of individuals in their early 20s ($M = 23.29$, $SD = 5.34$) who had been in monogamous, romantic relationships for an average of 3.5 years. On the whole, participant demographic characteristics mirrored the population of Austin, TX from which this sample was drawn. For more information about the demographic breakdown of this sample, see Table 1 below.

Table 1. Participant characteristics.

	Whole Sample	Females	Males
Age (*M*, *SD*)	23.29 (5.34)	22.78 (4.97)	23.41 (5.51)
Relationship length in years (*M*, *SD*)	3.55 (3.99)	3.54 (4.0)	3.56 (3.99)
Relationship status (%)			
In a committed relationship	62.93 %	60.34 %	63.79 %
Living with partner	30.17 %	32.76 %	29.31 %
Married	6.90 %	6.90 %	6.90 %
Sexual Orientation (%)			
Heterosexual	76.72%	68.97%	86.20%
Bisexual	12.07%	15.52%	8.60%
Other	11.21%	15.42%	5.20%
Ethnicity (%)			
Caucasian/White	45.70%	41.39%	50.00%
African American/Black	2.59%	1.72%	3.45%
Hispanic/Latino(a)	28.45%	29.31%	27.59%
Asian	19.83%	24.14%	15.52%
Middle Eastern	1.72%	1.72%	1.72%
Other	1.72%	1.72%	1.72%
Yearly Household Income (%)			
<$15,000	18.10%	22.41%	12.07%
$15,000–$25,000	10.34%	5.17%%	15.52%
$25,000–$50,000	14.66%	20.90%	8.62%
$50,000–$75,000	17.24%	8.62%	25.86%
$75,000 or more	39.65%	43.10%	37.93%
Sexual Function (% below clinical cutoff)	12.93%	22.41%	1.72%
Religion (%)			
Not Religious	28.44%	24.14%	32.76%
Atheist/Agnostic	27.59%	32.76%	22.41%
Spiritual/New Age	2.59%	3.45%	1.72%
Christian	31.90%	31.03%	32.76%
Jewish	2.59%	1.72%	3.45%
Islamic	0.86%	1.72%	0.00%
Hindu	3.45%	5.17%	1.72%
Buddhist	1.72%	0.00%	3.45%
Other	0.86%	0.00%	1.72%
Education (%)			
Some high school or less	0.00%	0.00%	0.00%
High school graduate/GED	14.66%	8.62%	20.69%
Some college/university	54.31%	58.62%	50.00%
University degree (approx. 3-4 years)	25.00%	25.86%	24.14%
Advanced degree (Ph.D., M.D., M.S., J.D., etc.)	6.03%	6.90%	5.17%

Equipment and measures

Self-report measures

Demographics

Demographic characteristics and relevant aspects of personal history were measured with a questionnaire that included items related to age, gender, race/ethnicity, educational attainment, socioeconomic status, frequency of sexual activity with partner, relationship length, and frequency of engagement in sexual positions included as part of the study protocol.

Sexual function

Sexual function in women was measured with the Female Sexual Function Index (FSFI), a validated 19-item measure that includes the following subscales: desire, sexual arousal, lubrication, orgasm, pain, and sexual satisfaction (Rosen et al., 2000). The FSFI has demonstrated impressive internal reliability ($r = 0.89 = 0.97$), test-retest reliability ($\alpha = 0.79$-0.88), and divergent validity with measures of relational satisfaction. The FSFI also has a clinical cutoff score that reliably discriminates between women with and without sexual dysfunction, with scaled scores below 26.5 indicating a clinically significant level of sexual dysfunction (Wiegel, Meston, & Rosen, 2005). The internal consistency of the FSFI in this particular sample was $\alpha = 0.87$. Sexual function in men was measured with the International Index of Erectile Dysfunction (IIEF) (Rosen et al., 1997). The 15-item IIEF contains five large factors, including erectile function, orgasmic function, sexual desire, intercourse satisfaction, and overall satisfaction, and also demonstrates impressive internal consistency ($\alpha = 0.91$). Like the FSFI, the IIEF has a validated clinical cutoff score, with scores below 25 on the Erectile Function subscale suggesting clinically significant levels of erectile dysfunction (Cappelleri et al., 1999). The internal consistency of the IIEF in the present sample was $\alpha = 0.75$.

Depression and anxiety

Depression and anxiety levels were included as control variables in this study. Levels of depression were assessed with the Patient Health Questionnaire-8, a valid diagnostic tool for assessing the presence and severity of depressive symptoms (Kroenke et al., 2009). The internal consistency of the PHQ-8 in this particular sample was $\alpha = 0.77$. Overall levels of anxiety were measured with the Generalized Anxiety Disorder-7 (GAD-7) (Spitzer, Kroenke, Williams, & Löwe, 2006), a popular diagnostic measurement tool for anxiety symptoms. The GAD-7 has demonstrated divergent validity with measures of depression and is a strong predictor of overall symptom severity. The internal consistency of the GAD-7 in the present sample was $\alpha = 0.88$.

Positive and negative affect

The potential effects of recent affective experiences on PS were controlled for with the Positive and Negative Affective Schedule (PANAS; Watson, Clark, & Tellegen, 1988). The PANAS is a 20-item measure that assesses the degree to which individuals are currently experiencing various positive and/or negative emotions. Internal reliability for the measure is strong for both the positive and negative dimensions of the scale ($\alpha = 0.86$-0.90; $\alpha = 0.84$-0.87). Additionally, the PANAS has demonstrated moderate test-rest reliability across eight-week periods for both the positive ($r = 0.54$) and negative ($r = 0.45$) dimensions of the measure. For this sample, the internal consistency for the negative dimension of the measure was $\alpha = 0.78$. The positive dimension of the measure had an internal consistency of $\alpha = 0.89$.

Psychophysiological equipment

Cardiac data were collected through Polar H10 chest straps connected to the Elite HRV app *via* bluetooth. Polar H10 straps, which employ impedance cardiography (ICG) technology, were recently validated as a "gold standard" measurement tool for examining cardiac interbeat intervals in an ambulatory fashion (Gilgen-Ammann et al., 2019). Moreover, during vigorous exercise, the Polar H10 straps maintained an overall accuracy rate of 99.4% (as compared to 99.6% at baseline) (Gilgen-Ammann et al., 2019). This suggests that even during increased physical activity (i.e., when individuals are engaged in sexual activity), cardiac readings should maintain a high level of accuracy. From the raw data, we derived heart rate (HR) values, based on the total number of cardiac beats per minute, as an overall index of autonomic arousal (Berntson, Quigley, Norman, & Lozano, 2017).

Procedure

Eligible couples were sent online links that contained informed consent materials. Once both individuals provided informed consent, they were given self-report measures to complete, independently, at their convenience. Within one week of the completion of survey measures, a researcher scheduled a time to leave the Polar H10 straps at an address specified by the couple. At that point, couples were asked to pick a day on which they planned to have penetrative sex. On that day, they were instructed to abstain from all alcohol and/or substance use. Prior to having sex, they were asked to complete a series of tasks while wearing the heart rate straps. These tasks have each been validated in other studies of PS in romantic relationships (Chatel-Goldman, Congedo, Jutten, & Schwartz, 2014; Ferrer, Helm, & Sbarra, 2012; Helm et al., 2014), and were counter-balanced to protect against carry-over effects. Instructional videos were provided to explain how to move through each study task. Tasks included the following:

- *Baseline Task.* Couples were instructed to go to separate rooms, place and pair the heart rate straps, and sit for five minutes while baseline cardiac activity was recorded. During this period, participants were instructed to move as little as possible and to refrain from engaging in other activities. This task was designed to isolate the effects of interpersonal synchrony from general similarities in physiological responding while also allowing for the collection of an independent baseline measure of autonomic arousal.
- *Gazing Task.* Couples were instructed to sit facing each other in comfortable chairs and to quietly look into each other's eyes for a period of five minutes. During this time, they were instructed to refrain from making any intentional facial gestures or vocal noises and to maintain eye contact to the best of their ability. Instructions specified that, if for any reason either individual became distracted, they were to refocus on their partner as soon as possible.
- *Mirroring Task.* Couples were instructed to engage in an 'imitation' task in which the couple continued looking at each other while actively attempting to "synch" physiologies for five minutes (without speaking to one another). Participants were told that the task was meant to be relatively vague and that they were not expected to know exactly how to engage with it. Instead, they were instructed to simply attempt mirroring one another on a physiological level in whatever manner they liked. Again, participants were instructed to refrain from making vocal noises or facial gestures and from attempting to communicate either verbally or non-verbally.
- *Hand Holding Task.* Couples were instructed to engage in a hand holding task in which they held one of their partners hands for a period of five minutes, without speaking. This task was designed to isolate the effects of touch, in general, from sexual touch.

After completing each of these tasks, couples were asked to wait at least two hours before engaging in sexual activity (to prevent carry over effects from the non-sexual tasks). During this time, couples were instructed to rate levels of positive and negative affect. Couples were then asked to place and pair the straps (if they were removed after the interpersonal tasks) and to begin recording prior to sexual activity. Couples were instructed to engage in sexual activity in three distinct phases, as described below. Across all tasks, they were instructed to restrict sexual activity to positions in which they could easily view each other's faces, as PS seems to occur largely in contexts in which individuals are able to perceive their partner's affective changes.

- *Foreplay.* Couples were instructed to engage in foreplay while in the same physical position (e.g., both laying down, both standing up, etc.). Couples were then instructed to engage in whatever kinds of intimate touch they preferred apart from penetrative sex. The goal for this task was to standardize levels of physical exertion that may obscure shared physiology.
- *Prescribed Position.* Couples were then instructed to engage in penetrative sex in a prescribed position (i.e., both partners on one side, facing each other). This position was chosen based on pilot data suggesting that it results in maximally similar levels of physical exertion between partners over time. To that end, the goal for this task, similar to the one above, was to standardize levels of physical exertion during penetrative sex specifically.
- *Free Form.* Couples were then instructed to engage in penetrative sexual activity in whatever position they preferred, for as long as they liked, provided that they continued to face one another. While this data collection context was less controlled than previously described tasks, it allowed for more ecological validity in terms of capturing the ways couples prefer to engage in sexual activity.

After completing sexual activity, the couples completed a rating form indicating whether or not they had experienced an orgasm (and if so, how many) during that particular sexual encounter. Participants then scheduled a time for the researcher to pick up the Polar H10 straps and provide compensation ($30 per individual, or $60 per couple). The completion of the study (i.e., when laboratory equipment was returned) was followed by a debriefing form that further detailed the goals of the study, thanked the individual for their participation, and directed participants to further information and resources. Participants were required to return Polar H10 heart straps in order to receive compensation. All equipment was sterilized between use. These procedures were approved by the institutional review board of the XX (blinded for review).

Data analysis

Raw data (i.e., a list of intervals between successive heartbeats [RR intervals]) were exported from the Polar app into an excel spreadsheet where they were visually inspected for movement artifacts. Because both individuals in a dyad need precisely the same number of datapoints for PS to be reliably calculated, complete case analysis procedures (i.e., the complete deletion of outliers from the datafile) were not appropriate. Instead, we employed multiple imputations to replace missing data (Nakagawa & Freckleton, 2011). If a datafile included movement artifacts for over 10% of the total file, that dyad was excluded from analysis. Once the datafiles were cleaned, they were subsequently loaded into Kubios Premium, a full featured HRV analysis software with functionality that supports time-domain, frequency-domain, and nonlinear RR analyses. Kubios calculated and generated values for HR, HRV, and HF-HRV that were entered into separate datafiles for each dyad. HR was calculated in an epoch length (i.e., 10 s) supported by prior literature (Cacioppo, Tassinary, & Berntson, 2016; Helm et al., 2018). Each of these metrics were calculated for epoch-lengths supported by prior literature (10 s for HR; 5 min for HRV and HF-HRV; Cacioppo et al., 2016; Helm et al., 2018). Prior to analysis, we detrended each of the physiological data files to prevent the spurious detection of PS.

Following guidance from Helm et al. (2018), we modeled PS by taking a growth curve modeling (GCM) approach, which allowed for the examination of within- and between-dyad effects. Beginning at the within-dyad level, a regression model was fit between the detrended physiological time-series data collected from both members of the couple. The beta-value from that regression model came to reflect the observed magnitude of PS for the dyad. Extending this model to a sample of dyads involved use of these coefficients as outcome variables. A GCM approach analyzes group-level data with regards to *dyad-level growth*. This is particularly useful when examining PS, as the magnitude of PS varies from couple to couple, and growth curve modeling allows for each dyad to serve as their own control. In this study, all equations were modeled with repeated measures. The slopes and intercepts were entered as random, thus allowing them to vary across participants. Importantly, the procedures above refer to the modeling of concurrent synchrony. To determine whether a lagged model better fit the data, we mirrored the procedures described above but while adding an autoregressive parameter. Indices of model fit (i.e., Akaike Information Criterion [AIC] values) were used to determine which models better fit the data.

The models described above control for the following: relationship length, sexual function, age, mean autonomic arousal levels, percentage of noise in the physiological data file, and levels of depression and anxiety. The sex-specific models (i.e., foreplay, prescribed position, and free form) additionally control for positive and negative affect immediately prior to sex and the number of orgasms reported during sexual activity. The foreplay model controls for the frequency with which the couple typically engages in foreplay and the prescribed position model controls for the frequency with which the couple typically engages in that particular sexual position. Finally, as couples engaged in freeform sex for variable lengths of time, we controlled for the duration of the overall sexual encounter.

Importantly, while the foreplay and prescribed position tasks lasted for five minutes each, couples had sex for a variable length of time in the freeform task. To address this, couples who had sex for shorter than 5 min in the free-form condition were excluded from this analysis ($N = 9$).

Results

Descriptive statistics

See Table 2 below for descriptive statistics on the primary physiological outcome measures of interest in this study. HR was calculated as a function of heart beats per minute, HRV was calculated as the root mean square of successive differences between normal heart beats, and HF-HRV was calculated as the peak frequency in Hz of the high-frequency band of HRV (with a range between 0.15-0.40 Hz).

Estimating physiological synchrony on heart rate data

Prior to examining model output, AIC values were calculated for all HR growth-curve models. These models were specified as both concurrent and also lagged by one measurement window (i.e., a HR lag of 10 s). The concurrent and lagged models were specified separately with both female and male partner HR over time modeled as the predictor (where the predictor "leads" the overall interaction). See Table 3 containing associated AIC values below.

Table 2. Descriptive statistics on HR (*M*, Std. Dev.).

	Female HR	Male HR
Baseline	75.5 (9.9)	73.2 (10.2)
Gazing	75.3 (10.5)	70.7 (10.1)
Mirroring	75.5 (10.5)	71.7 (9.5)
Handholding	75.6 (10.4)	71.8 (9.9)
Foreplay	84.1 (12.8)	81.7 (15.2)
Prescribed	85.6 (16.3)	97.3 (19.1)

Table 3. AIC values across models.

	Baseline	Gazing	Mirroring	Handholding	Foreplay	Prescribed	Freeform
Female Driving Concurrent	10259.93	10475.76	11526.87	10526.37	11507.96	9776.20	12024.63
Female Driving Lagged	9780.18	10098.45	11157.83	10085.40	11040.55	9334.94	11501.73
Male Driving Concurrent	10397.81	10366.17	10656.31	10530.06	11282.48	10216.48	12379.03
Male Driving Lagged	10010.81	9973.03	10217.85	10142.29	10792.07	9705.01	11840.11

Table 4. Model summaries for lagged growth curve models on HR data.

	Female Driving				Male Driving			
	ß	Std. Error	t-value	*p*-value	ß	Std. Error	t-value	*p*-value
Baseline	0.04	0.02	1.89	0.06	−0.01	0.02	−0.51	0.61
Gazing	0.06	0.03	2.49	0.01**	0.06	0.02	2.63	0.009**
Mirroring	0.17	0.03	5.55	<0.001***	0.07	0.01	3.72	0.0002***
Handholding	0.06	0.02	2.77	0.005**	0.07	0.02	2.95	0.003**
Foreplay	0.09	0.03	3.27	0.001***	0.08	0.02	3.51	<0.001***
Prescribed	−0.01	0.02	−0.43	0.667	0.06	0.03	1.88	0.06
Freeform	0.13	0.02	5.94	<0.001***	0.14	0.03	5.05	<0.001***

Significance codes, p > '***' 0.001 '**' 0.01 '*' 0.05.

Importantly, AIC values do not have an objective meaning or value on their own; they are only meaningful as a comparative index *between* models conducted on the same dataset (Akaike, 1973). Lower AIC values reflect better model fit overall. Without exception, the values reported above suggest that lagged models better fit our data. This was true across both male and female predicted models, and across all study tasks. That same consistency was *not* noted between the male- and female- driven lagged models. In some tasks, a slightly better model fit emerged on the lagged data where female partners were specified to drive the interaction (i.e., baseline, handholding, prescribed sex, and freeform sex). On other tasks, a stronger model fit was indicated when male HR was specified as the predictor of lagged female HR data (i.e., gazing, mirroring, foreplay). To that end, model summaries were examined for lagged data with both male and female partners driving the interaction (see Table 4 below).

Statistically significant physiological covariation emerged bidirectionally on all study tasks with two exceptions: the baseline task (female driving, ß = 0.04, $t = 1.89$, $p = 0.06$; male driving, ß=-0.01, t=-0.51, $p = 0.61$) and the prescribed position task (female driving, ß=-0.01, t=-0.32, $p = 0.667$; male driving, ß = 0.06, $t = 1.88$, $p = 0.06$). As hypothesized, beta values indicated a general increase in the magnitude of synchrony observed between non-sexual and sexual study tasks, suggesting that the dyads in this study manifested higher levels of physiological covariation while engaging in sexual activity. There are two exceptions to that pattern: a smaller beta value was noted in both directions for the prescribed position task, which did not reach statistical significance. Additionally, in the female-driven model, the strongest magnitude of synchrony was observed for the mirroring task (ß = 0.17, $t = 5.55$, $p < 0001$).

If correcting for multiple comparisons with a Bonferroni adjustment, these models would need to a reach a p-value of less than 0.003 to be considered statistically significant. After such corrections, the covariation observed in the gazing models (in both directions) and in the female-driven handholding model no longer reached statistical significance.

Discussion

This study sought to deepen our understanding of interpersonal autonomic synchrony and its role in human sexual activity. PS was measured in an ecologically valid, naturalistic setting: at home during sexual activity. Couples engaged in a series of non-sexual and sexual activities while cardiac activity was measured. As predicted, PS did not emerge during a baseline task (in which couples were not interacting with one another). As couples began interacting, statistically significant PS manifested, and for the most part, increased in intensity as the situation became more intimate. More exploratory analyses suggest that synchrony was better characterized by lagged (as opposed to concurrent) modeling procedures.

Before examining whether statistically significant PS emerged from these data, it was important to first determine if synchrony should be modeled as concurrent or lagged. To do so, we examined model fit indices for both concurrent and lagged models. Without exception, lagged models emerged as superior in terms of model fit. In some ways, this suggests a truly relational phenomenon is at play in these data. If a concurrently specified model better fit our observations, it would certainly be possible that the observed synchrony was a function of simultaneous responding to shared environmental cues. Lagged models, on the other hand, typically emerge when an individual is observing something in their social environment and incorporating that observation into their own psychobiological system (which would necessarily happen at a slightly later point in time). Lagged synchrony, to that end, may be better characterized as *attunement*; a pattern in which romantic partners notice subtle cues in their partner's affective state and move to modulate their own autonomic nervous system to match those cues.

After finding that lagged models better fit these data, we then examined whether statistically significant covariation emerged between the heart rate signals of romantic partners. As hypothesized, PS did not emerge during a baseline condition when couples were not interacting with one another. Importantly, this suggests that synchrony is not merely a function of similarities in biological and/or oscillatory systems because, if it were, PS would emerge regardless of whether a context were social or not. The lack of discernable PS during the baseline condition provides a validity check with regards to the specificity of PS, increasing our confidence that the PS observed during non-sexual and sexual interpersonal tasks reflects something specific to the social environment itself.

Interestingly, before corrections for multiple comparisons, statistically significant PS emerged in all other study conditions in both male- and female-specified models with one exception: sexual activity in a prescribed sexual position (both partners laying on their sides and facing one another). It is possible that synchrony did not arise in this context because of its artificiality: when couples engaged in sex in a manner that dramatically differed from their typical behavior, they could have been reminded of their study participation. It's possible the introduction of these observation effects reduced the degree to which couples were able to meaningfully attune to one another. Similarly, it's possible that the sexual position prescribed here was not preferred by our participants (on a scale reflecting the frequency with which couples typically engaged in this sexual position [from 1-5], the mean was 1.82, which was notably different than the mean of 3.91 observed for the foreplay task). To that end, it's possible that this condition inadvertently introduced a less sexually desirable context for our participants, which then limited the development of PS. Finally, regardless of preference for the position itself, it's possible that asking couples to engage in only one sexual position over time limited the capacity for PS to develop by reducing the ability for participants to respond to partner cues. If PS develops during sexual activity as a function of scanning for, identifying, and reacting to partner affective states, then the inability to shift positions in response to a partner's preference may prevent the development of physiological covariation over time. Notably, PS did develop in sexual contexts that allowed for the shifting of positions according to preference.

To that end, while PS did not develop during the prescribed position task, statistically significant synchrony did arise during both the foreplay and freeform conditions. These data provide at least preliminary evidence that physiological attunement develops in arousal-specific contexts. With only one exception (i.e., mirroring, specified as female-driven), the magnitude of synchrony increased between non-sexual and sexual study activities. This suggests that there is something specific to sexual behavior that increases autonomic covariation. While previous research has found that non-sexual touch increases autonomic coupling between partners (Chatel-Goldman et al., 2014), that pattern did not emerge from these data (i.e., the magnitude of synchrony did not increase during the handholding condition). That synchrony increased during sexual activity but not during a handholding condition suggests that the higher magnitude of synchrony observed during sexual behavior is not attributable to the effects of touch in general. If touch is not responsible for the increase in synchrony observed during sexual behavior, it's possible that PS increased here as a function of situational intimacy.

While there has been tremendous interest in studying the psychophysiological aspects of sexuality, no studies to date have taken a dyadic psychophysiological approach; or more specifically, no studies have looked at the *connection* between the psychophysiological signals of partners during sex. Similarly, while researchers have begun to acknowledge the inherently interpersonal nature of sexuality, no prior work has tied the relational components of sex to physiology. To that end, this is first study to find evidence for the reliable emergence of physiological covariation during sexual activity or any context involving sexual arousal. The presence of PS during sex is theoretically and clinically important; it suggests that our sexual experiences are not only regulated by our own physiological cues but also those of our sexual partners. It is our hope that this study can provide the rationale for additional research exploring the role of shared physiology in sexual relationships. It is also our hope that these findings can help researchers design future studies with more specificity by providing evidence that (1) PS can be reliably detected during sexual activity and (2) that such synchrony seems to present as lagged in nature.

From an applied perspective, the implications of this work require further research before being translated to clinical recommendations. Research clearly demonstrates the importance of certain psychophysiological indices for sexual function (i.e., levels of SNS arousal, levels of blood flow in the genitals, etc.; e.g., Meston, 2000). Indeed, many clinical treatments have been developed for sexual dysfunction that specifically seek to modulate ANS activity (i.e., exercise before sex for individuals who may not have sufficient levels of SNS arousal during sexual activity, biofeedback techniques to increase the balance or flexibility of the overall ANS; e.g., Lorenz & Meston, 2012; 2014; Stanton, Boyd, Fogarty, & Meston, 2019). Results from this study suggest that individuals dynamically regulate their autonomic nervous system *to* a partner during sex. To that end, it's possible that existing interventions targeting ANS activation may benefit from a dyadic component that accounts for this pattern of physiological attunement between partners which may, itself, shift the nervous system during sexual activity. Certainly, further research is needed before designing and testing such interventions.

From a theoretical perspective, this study provides several notable contributions. Firstly, it is theoretically interesting that lagged modeling procedures better fit these data. This suggests a pattern not simply of synchronization but of attunement, with couples incorporating cues from their partner's experience into their own autonomic response at a slightly later point in time. On another note, with only one exception, PS increased in magnitude between the non-sexual and sexual study tasks (or, at least those in which statistically significant PS emerged). Other research has demonstrated that synchrony increases based on the intimacy levels that characterize the relationship *overall* (e.g., Konvalinka et al., 2011), but this is the first study to measure differences in synchrony during increasingly intimate interactions within the same couples. To that end, these results provide preliminary evidence that synchrony increases as a function of situational intimacy or engagement in intimate behaviors. This is theoretically interesting because it suggests that synchrony does not only vary *between* dyads but also *within* dyads depending on a range of contextual factors. Importantly, this finding reinforces the larger theory underlying the PS literature: that biological covariation reflects something important about the connection present in a social exchange.

Indeed, the theory that synchrony indexes something important within a social exchange underscores why this is an important area of study for romantic relationships more broadly and sexual relationships more specifically. Patterns of physiological linkage between romantic partners are linked to the perceived quality of their relationships. Research suggests that couples who manifest higher levels of physiological synchrony also tend to be more relationally satisfied, better able to identify partner affective states, and more likely to demonstrate dyadic empathy (Timmons et al., 2015). You could imagine that the each of these features could improve sexual experiences simply by way of improving the overall relationship and/or increasing feelings of intimacy. Alternatively, it's possible that synchrony is relevant to sexuality because (1) synchrony during sexual activity facilitates attunement, helping couples to remain calm, relaxed, and focused on relational cues during sex or (2) synchrony helps up-regulate the autonomic nervous system during sexual activity, facilitating adequate sympathetic activation, which is particularly important for female sexual arousal. Given that this analysis did not include discrete measures of sexual satisfaction, it is impossible to speak to the relevance of synchrony in this context for sexual quality or satisfaction. Future studies should seek to relate patterns of synchrony during sexual activity to measures of sexual satisfaction, and if synchrony is significantly related to satisfaction, interrogate the specific mechanism underpinning that relationship.

While this study offers several important clinical and theoretical contributions to the literature, there are several significant limitations worth mentioning. Firstly, this study was conducted on a largely homogenous sample. The inclusion and exclusion criteria defined as part of our methodology intentionally selected for such homogeneity—given the novelty of this work, we were interested in examining this phenomenon in a sample without meaningful barriers to synchrony (i.e., sexual dysfunction, physical health concerns, etc.) While this was an intentional methodological choice, it significantly limits the generalizability of these findings to populations of young, physically healthy, heterosexual, and largely sexually functional couples. Similarly, the couples included in this study all reported being in monogamous, heterosexual relationships. This choice provided the capacity to examine gender differences, but meaningfully limited our ability to extend findings to a broader and more inclusive range of relational contexts.

This study was designed to examine sexual relationships in a more ecologically valid and naturalistic way than is possible in laboratory-based research. One of the strengths of this study design is that couples were measured at-home while engaging in sexual activity in a manner that mostly reflected their own preferences. With that being said, ecological validity comes with a cost to internal validity and, without manipulation checks, we have no information about the degree to which participants appropriately completed study tasks. Relatedly, it's possible, and indeed probable, that introducing a study protocol into a naturalistic environment altered that environment in some way. For instance, the act of wearing heart rate straps may have reminded couples of their study participation and subsequently shifted their autonomic or sexual responses. Similarly, it's possible the heart rate straps made it more difficult to engage in a number of preferred sexual positions and, to that end, negatively impacted the quality of the sexual encounter. On the other hand, this study introduced a series of new relational and sexual experiences and could have even functioned as an inadvertent treatment of sorts—*improving* sexual experiences by introducing both intimacy and novelty. We have no way of evaluating whether and/or how any of these possibilities occurred or impacted the observed effects.

Other limitations for this study include the relatively high drop-out rate (45%). It's possible that the couples who remained in our study were meaningfully different (e.g., more sexually satisfied or open) than those who discontinued their participation. This point is notable because sex research, more generally, tends to suffer from selection bias issues, with individuals participating in such studies reporting higher levels of sexual openness and satisfaction than average. On another note, we did not include a measure of perceived synchrony, and thus it is unclear if participants had a sense of whether they were experiencing a synchronous interaction. This will be important for future studies looking to extend these findings to more clinically relevant settings (i.e., attempts to increase synchrony).

There are a number of future directions that could deepen this burgeoning area of research. Firstly, results from the present study have limited applicability outside of committed, heterosexual partnerships. It will be extremely important to test these effects in more representative and inclusive samples moving forward. On another note, the results presented here control for different levels of sexual function between participants. In future research, it will also be interesting to compare differences in PS between groups of participants with and without clinical sexual dysfunction. Given that sexual dysfunction has implications for autonomic nervous system functioning, particularly during sexual arousal, patterns of autonomic exchange between partners may also differ as a function of sexual difficulties. Many existing treatments for sexual dysfunction seek to modulate the ANS. A deeper understanding of how partners already modulate their autonomic nervous system during sex in connection with their partner could serve to bolster the effects of these existing treatments. Additionally, as ambulatory psychophysiology measurement technology improves, there may be potential for the synchronous measurement of genital arousal during sexual activity. Such technology could facilitate an understanding of whether and/or how ANS synchrony translates to sexual arousal synchrony.

Finally, and most importantly, there is a desperate need for more studies in the larger PS literature that take an experimental approach. To date, there has only been one experimental study finding that biofeedback can evoke PS, and that by modulating PS, dyadic empathy rates improve (Salminen et al., 2019). That is the only available evidence that (1) PS can be modulated and (2) relational outcomes improve as a function of shifts in synchrony. Otherwise, the directionality of these relationships remains entirely unclear. Certainly, there is potential for research on physiological synchrony to inform clinical practice given the extensive evidence that PS is relevant for relational outcomes. With that being said, even an extensive body of correlational research cannot sufficiently guide the development of clinical recommendations or practice guidelines. To that end, it would be useful to (1) modulate relational/sexual outcomes by way of couples therapy and observe what happens to synchrony during sexual activity as a result and to (2) modulate synchrony by way of dyadic biofeedback and observe what happens to sexual/relational satisfaction as a result. These next steps are necessary to determine the ultimate clinical and theoretical implications of this work.

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