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1 **Cover Page**

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3 WOMEN'S EMOTIONAL AND SEXUAL ATTRACTION TO MEN ACROSS THE MENSTRUAL CYCLE

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9

10 Rei Shimoda is currently unaffiliated.

11 Anne Campbell is deceased.

12

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17 inspirational supervisor and colleague. We wish to thank Eric Cator for statistical advice and are grateful  
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19

20 **Data Accessibility**

21 Analyses reported in this article can be reproduced using the data provided by Shimoda, Campbell, and

22 Barton (2017).

23 **LAY SUMMARY**

24 Have women evolved to shift their attraction to particular types of men at peak fertility? Methodological  
25 issues, which we address in this article, have led to empirical disagreement. We investigate women's  
26 attraction for men in relation to the women's cycles. Our results suggest further study of potential non-  
27 adaptive factors may be needed.

28

29 **WOMEN'S EMOTIONAL AND SEXUAL ATTRACTION TO MEN ACROSS THE MENSTRUAL CYCLE**

30 **ABSTRACT**

31 There is ongoing debate about how and why the menstrual cycle affects women's attraction to men.  
32 According to the dual sexuality hypothesis, women form pair-bond relationships with men who provide  
33 care but also obtain genetic benefits by biasing mating effort towards men with high-fitness genes during  
34 the fertile phase. By contrast, the commitment hypothesis proposes that attachment bonds with primary  
35 partners function to strengthen pair-bond relationships by enhancing in-pair attraction at the fertile  
36 phase, rather than extra-pair attraction. We tested these hypotheses by measuring women's daily sexual  
37 and emotional attraction towards men over the whole menstrual cycle. We employed (1) a urinary  
38 luteinizing hormone test to determine the day of ovulation, (2) a five-part classification of menstrual cycle  
39 that identifies a distinct peri-ovulatory phase, and (3) individualized phase identification for each  
40 participant. There was a mid-cycle rise in extra-pair sexual desire. Women gave and received more care  
41 from partners during the menstrual than the mid-cycle phases. Partner's sexual attractiveness and  
42 mutual commitment did not moderate these findings. The results do not support either the dual sexuality  
43 or commitment hypotheses, and imply that female self-reported sexual desire is not strictly dependent on  
44 cyclic hormonal changes. Our results are more consistent with a recently proposed 'spandrel' hypothesis,  
45 positing cycle phase effects as a non-functional by-product of raised estradiol. Additionally, we found  
46 that, with the date of ovulation estimated by luteinizing hormone tests, 45% of ovulations were  
47 misclassified by the backward counting method, which urges caution in interpreting results based on  
48 counting methods.

49 **KEY WORDS**

50 Ovulation, menstrual cycle, romantic relationships, mating strategy, luteinizing hormone tests, sexual  
51 desire.

52

## 53 INTRODUCTION

54           There has been debate about the extent to which women's attraction to in-pair and extra-pair  
55 partners fluctuates over the menstrual cycle. According to the 'dual sexuality' hypothesis (reviewed in  
56 Thornhill and Gangestad 2008), women pursue a dual sexuality strategy, favoring genetic quality in males  
57 with whom they mate whilst forming long-term pair-bonds with males that provide care and/or resources.  
58 Evidence is provided by studies showing that during periods of peak fertility and when seeking short-term  
59 partners, women's sexual preferences shift to favor men who possess phenotypic indicators of 'good  
60 genes', such as low fluctuating asymmetry (signaling developmental stability) and more masculine traits  
61 such as androgen-mediated olfactory cues (Havlíček et al. 2005; Thornhill et al. 2013) and dimorphic facial  
62 shape (Penton-Voak et al., 1999, but see Gildersleeve et al. 2014a). Such testosterone-dependent traits in  
63 sexually selected species are thought to be costly and therefore honest signals of condition because high  
64 circulating levels of testosterone compromise immune responses (Folstad and Karter 1992). Partnered  
65 women whose mates are of lower genetic quality are proposed to be especially likely to be attracted to  
66 extra-pair mates during peak fertility (Gangestad et al. 2005). Supporting this, women with less sexually  
67 desirable partners experience greater sexual attraction to other men when fertile and, in some cases, a  
68 decrease in attraction to their primary partner (Larson et al. 2012). According to the dual sexuality  
69 argument, the extent to which the primary partner lacks phenotypic indicators of gene quality moderates  
70 the strength of women's extra-pair sexual desire.

71           An alternative hypothesis – the 'commitment' hypothesis - implicates pair-bond attachment as a  
72 key moderator. Eastwick and Finkel (2012) argued that, because the evolution of the ovulatory shift  
73 adaptation is likely to have preceded the reproductive pair bonds, a new adaptation has occurred to  
74 counter this cycle shift effect, thereby supporting intersexual cooperation and reducing antagonistic  
75 coevolution. This adaptation depends upon the attachment bond which cements long-term commitment  
76 and redirects women's sexual desire at high fertility toward the partner, rather than to extra-pair men. In

77 support of this, they found that women who were strongly bonded to their partner experienced more  
78 intimate physical contact with them on high fertility days. In weakly-bonded women however, peak  
79 fertility was associated with decreased intimate contact with their partner. These two hypotheses make  
80 specific predictions regarding the interaction between their favored moderator (sexual attractiveness or  
81 relationship commitment) and cycle phase on women's evaluations of their long-term relationships and  
82 desire for in-pair and extra-pair men.

83 Previous studies have not produced consistent findings. Congruent with the commitment  
84 hypothesis, Pillsworth et al. (2004) found that extra-pair desire during the fertile phase was reduced by  
85 relationship satisfaction. However, other findings have failed to find support. Although Pillsworth et al.  
86 (2004) found in-pair sexual desire was higher on more fertile days, this effect was not moderated by  
87 relationship commitment, satisfaction or length. Similarly, Larson et al. (2012) found no evidence that  
88 relationship quality or length moderated fertility-related changes in in-pair or extra-pair attraction.  
89 Larson et al. (2013) included a measure of investment attractiveness, operationalized as high financial  
90 status and desirability as a long-term partner. To the extent that women's positive evaluation of these  
91 qualities might be associated with greater commitment to the relationship, the commitment hypothesis  
92 would predict an interaction between partner's investment attractiveness and women's ratings of  
93 relationship quality at high versus low fertility. However (and contrary to prediction) the only (marginally)  
94 significant interaction indicated that women partnered with men of high investment attractiveness  
95 reported decreased (rather than increased) closeness at high compared to low fertility. Pillsworth and  
96 Haselton (2006) found no interaction between investment attractiveness and phase on either in-pair or  
97 extra-pair sexual desire. The bulk of empirical research to date has been inspired by and has  
98 preferentially supported the dual sexuality hypothesis. In the most detailed analysis of relationship  
99 variables to date (Larson et al. 2013), phase interacted with ratings of partner's sexual attractiveness for  
100 three measures of relationship quality (satisfaction, closeness, faults and virtues). Women partnered by

101 more sexually attractive men felt closer to them and more satisfied with the relationship during the fertile  
102 phase than the non-fertile phase. Women with less attractive partners experienced decreased closeness  
103 and found more faults with them at high versus low fertility.

104 Two recent meta-analyses of over 50 studies, which examined potential cycle shift effects on  
105 purported 'good gene' traits, reached different conclusions about the strength of support for the cycle  
106 shift effect (Gildersleeve et al. 2014a; Wood et al. 2014). The fierce debate about this inconsistency  
107 (Harris et al. 2014; Wood and Carden 2014; Gildersleeve et al. 2014b) centered upon three key  
108 methodological issues which we address in the design of the present study. One important issue  
109 concerns the estimation of the fertile period. There is wide variation in the placement and size of the  
110 fertile window used by researchers. The majority of studies base their estimate on the reported date of  
111 previous menses or the expected or actual date of next menses, assuming a 28-day cycle (despite  
112 evidence of wide variability in cycle length, Münster et al. 1992). For instance, in studies reviewed in  
113 Gildersleeve et al.'s (2014a) meta-analyses (data collection ended in December 2012), around 92% of  
114 studies published before 2010 and 83% of studies published after 2010 used counting methods (see  
115 Gonzales and Ferrer 2016). Ovulation is estimated using either a forward counting (from the first day of  
116 last menses) or backward counting (from first day of the next menses) methods, with the latter method  
117 proving the more valid estimate (Gangestad et al. 2016). The number of days included in the fertile  
118 period has ranged from 5 to 11 (Harris et al. 2013). Other researchers use a continuous measure of the  
119 probability of pregnancy from a single act of intercourse on the day of data collection (calculated by  
120 Wilcox et al. 2001). Importantly, these methods are not very accurate in assessing whether or when  
121 ovulation occurred. The most precise procedure to identify the ovulation might be transvaginal  
122 ultrasonography (e.g., see Cobey et al. 2013). However, it is both invasive and costly. Since the menstrual  
123 cycle is under the control of four primary hormones – follicle-stimulating hormone, luteinizing hormone  
124 (LH), estrogen, and progesterone – it is possible to estimate the timing of ovulation by measuring

125 hormonal fluctuations. These methods include measurement of daily hormone levels (e.g., Direito et al.  
126 2013), assessment of weekly hormone levels (e.g., Hahn et al. 2016), and the combination of counting and  
127 hormonal methods (e.g., Roney et al. 2011). Another less costly method is the measurement of LH alone.  
128 A sudden surge in LH triggers ovulation; therefore, ovulation can be conveniently estimated by the use of  
129 commercial instant tests which assay LH surge (e.g., see Gangestad et al. 2005; Pillsworth and Haselton  
130 2006; Larson et al. 2013). These hormonal methods are naturally sensitive to individual differences in the  
131 way hormones fluctuate and how it affects women's cycles. Regarding LH, a study showed that in 75% of  
132 cycles ovulation occurred around the first LH surge (Direito et al. 2013), implying that the accuracy of LH  
133 tests can be improved by administering tests daily until the initiation of an LH surge (Gangestad et al.  
134 2016). In our study, we administered LH tests daily during individually tailored test windows. We use it in  
135 the current study to establish a distinct 6-day peri-ovulatory phase during which conception is most likely  
136 (Wilcox et al. 1995).

137         A second concern is with study design. Some studies employ a between-groups design  
138 comparing fertile and non-fertile groups on a dependent variable of interest. A repeated measures design  
139 is preferable because it reduces the noise associated with between-group analysis and dramatically  
140 reduces the sample size required to achieve adequate power (Gangestad et al. 2016). However, most  
141 studies to date have employed a between subjects design (e.g., 62% of reviewed studies in Gildersleeve et  
142 al. 2014a's meta-analysis study, see Gonzales and Ferrer 2016) and taken only two measures, one each  
143 from fertile and non-fertile phases. Measurement reliability is increased by aggregation, so we employed  
144 a daily diary method to calculate ratings across an entire menstrual cycle. This also allowed us to more  
145 accurately record the date of menses onset rather than relying on the recollection of participants, around  
146 20% of which is erroneous by at least 3 days (Wegienka and Baird 2005).

147         A third issue is the importance of tailoring phases to the individual cycle of each participant.  
148 Rather than assuming a 28-day cycle, we individualized each participant's cycle by calculating five phases

149 (menstrual, follicular, peri-ovulatory, luteal, premenstrual). This also permits a more sensitive analysis by  
150 identifying a peri-ovulatory phase (when fertilization is possible), distinct from the broader follicular  
151 phase which is sometimes used as a proxy for the fertile window. We also distinguish the premenstrual  
152 phase from the broader luteal phase in light of the fact that up to 80% of women experience negative  
153 premenstrual psychological changes, as well as a significant decrease in sexual desire (Yang et al. 2010).

154 The primary aim of the study was to examine cycle phase effects, specifically whether they are  
155 moderated by partner physical attractiveness or by mutual commitment. A secondary aim was to address  
156 the methodological debate about the potential impact of differences in estimating fertile and non-fertile  
157 phases. We re-analyzed our data following the description given by Haselton and Gangestad (2006) in  
158 their report of how partner's sexual-versus-investment attractiveness (SIA) moderated cycle phase effects  
159 on extra-pair attraction. Their analysis employed a within-participant two-phase classification scheme.  
160 We compared these results with those obtained using our five-phase scheme individually tailored around  
161 the hormonally-estimated day of ovulation.

162 Recently, after the completion of our study, Havlíček et al. (2015a) proposed a 'spandrel'  
163 hypothesis which asserts that the within-cycle shift in women's mate preferences is not in itself an  
164 adaptation, but is instead a by-product of the calibration of individuals' behavior to their levels of  
165 reproductive hormones and associated attractiveness. Although there is no uniform agreement about  
166 which hormones are specifically associated with sexual desire, evidence suggests that estradiol was  
167 positively and progesterone was negatively associated with female sexual desire (Roney and Simmons  
168 2013; Roney and Simmons 2016). Estradiol is known to increase around ovulation and progesterone to  
169 peak at the mid-luteal phase (reviewed in Barbieri 2014). Thus, the spandrel hypothesis views the cycle  
170 shift effect as a non-functional by-product of raised estradiol. In the discussion section, we will mention  
171 some connections between our work and this new hypothesis.

## 172 **METHODS**

**173 Participants**

174 Participants were 40 naturally cycling heterosexual women who received a nominal payment  
175 and/or course credits for their participation. They were recruited through a participant pool in a  
176 psychology department (Durham University) or via social networking systems outside the department. Of  
177 the original sample of 40 women, 5 women were dropped from the analysis due to the use of mood-  
178 altering medication, relationship termination, illness, or irregular menses. The final sample was  
179 composed of 35 women (median age = 20.0 year-old 95%CI [20.50, 24.30]) all of whom were in a  
180 committed romantic relationship (median relationship length = 1.88 years 95%CI [1.79, 4.63]). The  
181 women described themselves as European (63%), Asian (31%), North American (3%), and South American  
182 (3%). One of the women had 2 children. Having children could plausibly affect women's sexual desire,  
183 but it was not possible to test the effect, since there was only one relevant participant in our sample.  
184 Nonetheless, exclusion of this woman's data did not alter results and her data were retained.

**185 Procedure**

186 The study was approved by the Durham University Psychology Committee on Ethics. At an initial  
187 session, the study was explained to participants and they gave informed consent. They provided  
188 demographic information and completed an evaluation of their partner (see below). Participants were  
189 provided with urinary LH test sticks (Clearblue® Easy Digital Ovulation Test) and given directions on how  
190 to use the tests.

191 After the initial session, participants completed daily questionnaires via a dedicated website.  
192 After participants notified us via email that they had started their menses, they were emailed a link to the  
193 online questionnaire every morning. This acted as a daily reminder for participants and enabled us to  
194 send a special reminder during a LH test window (see below). The reminders and links continued until  
195 participants informed us of the onset of their next menses. Participants were not able to see their  
196 previous responses.

197 Participants took the LH tests during their cycle. LH surge generally occurs 36 -44 hours prior to  
198 ovulation (reviewed in Barbieri 2014), and ovulation is believed to occur 15 days prior to the onset of next  
199 menstruation in a standard 28-day cycle(Gangestad et al. 2016). In order to schedule the LH test window  
200 tailored to each woman, information about the date of the first day of previous menses, usual cycle  
201 length, and the length of her previous cycle (obtained at the initial session) was used in conjunction with  
202 the date of the onset of her next menses (emailed by the participant on the day she began her daily  
203 ratings) to identify the predicted date of her subsequent menses. The likely date of ovulation was then  
204 estimated using the backward counting method. Women were asked to test daily for 10 days, beginning  
205 5 days before the estimated LH surge day.

## 206 **Measures**

### 207 ***Intake questionnaire***

208 At an initial meeting, participants provided information on age, ethnicity, use of hormonal  
209 contraceptives, menstrual cycles, and length of current relationship with their primary partner.  
210 Participants rated their partner's physical attractiveness ("*How physically attractive is your partner?*"),  
211 level of commitment from and to their partners ("*How committed is your partner to you?*" and "*How*  
212 *committed are you to your partner?*"), and level of partner's financial security ("*How financially secure is*  
213 *your partner?*") using a visual analogue scale (0 = Not at all to 100 = Very).

### 214 ***Daily questionnaires***

215 The daily questionnaire was composed of eight items. Six items were designed to assess six pair-  
216 bond relationship dimensions derived from a previous factor analytic study (Shimoda 2014). These were:  
217 Obsession, "*My partner always seems to be on my mind.*"; Care-receiving, "*I feel that my partner*  
218 *understand me when I have a hard time.*"; Care-giving, "*I am prepared to be counted on by my partner*  
219 *and I will always be there for and care about my partner in times of need.*"; Separation distress, "*I would*  
220 *feel despair if my partner left me.*"; In-pair sexual desire, "*How strong is your desire to engage in sexual*

221 *activity with your partner?”*; and Extra-pair sexual desire, *“How strong is your desire to engage in sexual*  
222 *activity with a person you find attractive (not your partner)?”*. Participants were instructed to think about  
223 their feelings on that day and rate the applicability of the six statements on a 5-point scale (*Disagree*  
224 *Strongly to Agree Strongly* for emotional items and *No Desire to Very Strong Desire* for sexual desire  
225 items). Participants also rated their mood, *“How is your mood right now?”* (Worst = 0 to Best = 100). In a  
226 10-day window during which women used the test sticks daily, they were also asked to report the result  
227 of their ovulation tests.

### 228 **Menstrual phase coding**

229 The cycle was divided into five phases as follows. The mean length of menstruation is 5 days  
230 (reviewed in Barbieri 2014); hence, the 5 consecutive days from the onset of menses were coded as the  
231 menstrual phase. Conception probability is highest during a 6-day interval that ends in ovulation day  
232 (Wilcox et al. 1995). Thus, the peri-ovulatory phase of peak fertility was coded as 6 successive days (from  
233 4 days before the day of LH surge to 1 day after the day of LH surge). With these milestones established,  
234 the follicular phase was identified as the time between the end of menstruation and the start of the peri-  
235 ovulatory phase, the luteal phase as the interval between the end of the peri-ovulatory phase and 3 days  
236 prior the reported onset of the next menses, and these 3 premenstrual days as the premenstrual phase.  
237 Hence, whereas the length of the menstrual, peri-ovulatory, and premenstrual phases was common to all  
238 participants, the length of the follicular and luteal phases differed depending on each individual’s cycle.

### 239 **Statistical analyses**

240 A 2-level linear mixed model (SPSS 23 IBM) was used to analyze the daily reports of the six  
241 relationship measures (i.e., obsession, care-giving, care-receiving, separation distress, in-pair and extra-  
242 pair sexual desire). The daily reports (level 1) nested within participants (level 2). We first examined  
243 whether the six relationship measures varied as a function of cycle phase (Model 1). This base model was  
244 constructed from cycle phase as a within-subjects variable with 5 time points (menstrual, follicular, peri-

245 ovulatory, luteal, premenstrual phases). We also included an intercept for participants as a random effect.  
246 A random slope for participants was not added as it yielded convergence problems. Mood may vary  
247 systematically over the cycle for hormonal and lifestyle reasons. Thus, a main cycle effect on mood was  
248 also tested (with the intercept also allowed to vary randomly, Model 2). We also entered mood as a time-  
249 varying covariate to the base model (Model 3). We then examined whether the partner's physical  
250 attractiveness or the couples' mutual commitment moderated the effect of phase on any of the six  
251 dependent measures. Women's evaluations of their partners' physical attractiveness and mutual  
252 commitment (created by summing commitment to and from partners) were entered into the base model  
253 simultaneously as between-subjects covariates to examine interactions with cycle phase on the six  
254 relationship measures (Model 4). These variables were mean centered so that main effects of phase  
255 would be estimated at mean levels of partner ratings. Pairwise contrasts were conducted to compare  
256 each phase. We used a first-order autoregressive covariance structure for the repeated measurements.  
257 The estimation method was restricted maximum likelihood.

258         Additionally, we re-analyzed our data using sexual-versus-investment attractiveness (SIA) as a  
259 moderator in a two-phase classification scheme. We adopted the scheme used by Haselton and  
260 Gangestad (2006) due to their clear description of the decision rules used to assign participants to fertile  
261 and non-fertile phases. To mimic their SIA variable ('sexual attractiveness' minus 'long-term  
262 attractiveness' in their study), SIA was estimated by subtracting women's ratings of their partner's  
263 financial security from physical attractiveness ratings. SIA represents the extent to which men have  
264 relatively more long-term (indicated by negative values) or short-term (indicated by positive values)  
265 partner qualities (Haselton and Gangestad 2006). We also recoded our data so that phase was a binary  
266 independent variable (fertile versus infertile). Fertile days included the estimated day of ovulation (i.e.,  
267 15 days prior to the onset of the next menses) and the 4 days preceding it. Infertile days spanned from  
268 the third day immediately following the estimated day of ovulation to 3 days prior to menstruation.

269 There were 34 women in the analyses (one participant who took emergency contraceptives was  
270 excluded). Using the two phases as a repeated measures variable and SIA (mean-centered) as the  
271 covariate, we used repeated measure ANCOVA with the six dependent measures being the average of  
272 each scale computed for each phase. Following interactions, tests of simple effects were conducted using  
273 directed tests (see Haselton and Gangestad, 2006; Rice and Gaines, 1994), assigning a critical value of  $P <$   
274  $0.04$  to the predicted direction and  $P < 0.01$  to the unpredicted direction ( $P_{dir}$ ). This analysis was repeated  
275 using our five-phase classification.

## 276 RESULTS

### 277 Pre-analyses

278 Participants completed an evaluation of their partner and relationship at the initial session, which  
279 was scheduled randomly. This could be an issue as the evaluation could be influenced by cycle phase  
280 effect. Using the dates of the initial sessions, the dates of the onset of previous menses (a cycle just  
281 before participating in our study), and the cycle patterns found in our study, we made a rough estimation  
282 of which phases women were in on the initial session day. The distribution was estimated as 22.9%,  
283 17.1%, 22.9%, 25.7%, and 11.4% for the menstrual, follicular, peri-ovulatory, luteal, and premenstrual  
284 phases, respectively. We compared the expected and observed frequencies of initial sessions in each  
285 phase using a one-sample Chi-square test. For the menstrual, peri-ovulatory, and premenstrual phases,  
286 the phase length was fixed for every woman in the current study design, which was 5, 6, and 3,  
287 respectively. For the follicular and luteal phases, the observed median length of phases was 6 and 10,  
288 respectively. Thus, with 35 samples, the minimum expected count of initial sessions was less than 5 (3.5)  
289 for the premenstrual phase. Following the recommendation (McDonald 2014), we pooled the  
290 premenstrual phase with the adjacent luteal phase. A result showed that the expected and observed  
291 frequencies of initial sessions were not significantly different from each other,  $\chi^2(3) = 1.40$ , exact  $P = 0.70$ .  
292 In addition, a Kruskal-Wallis H test was conducted to determine whether scores of partner physical

293 attractiveness and mutual commitment were different across the four phases (the luteal and  
294 premenstrual phases were pooled). Levene's test indicated that homogeneity of variance assumption  
295 was met for partner attractiveness ( $P = 0.33$ ) and mutual commitment ( $P = 0.50$ ). Median scores for the  
296 menstrual, follicular, peri-ovulatory, and luteal/premenstrual phases for partner physical attractiveness  
297 were 80.0, 89.0, 73.0, and 77.0, and for mutual commitment 191.0, 190.0, 176.5, and 183.0, respectively.  
298 Results showed that the scores were not significantly different across the phases for partner  
299 attractiveness,  $\chi^2(3) = 7.52$ ,  $P = 0.06$ , and mutual commitment,  $\chi^2(3) = 3.27$ ,  $P = 0.35$ . The potential cycle  
300 phase effect on the partner evaluation could not be controlled, but these rough analyses indicated that  
301 the initial sessions were distributed throughout the cycle, and the scores did not differ among phases.

302 Values of skewness and kurtosis showed departures from normality for care-giving, separation  
303 distress, extra-pair sexual desire, and mutual commitment. Regarding partner physical attractiveness,  
304 one case had an extremely low score ( $z = -3.84$ ). In keeping with the recommended practice (Tabachnick  
305 and Fidell 2013), the five variables were log or square root transformed. It improved the normality of  
306 these variables and there was no outlier in the transformed values.

### 307 **Menstrual cycles**

308 The participants returned a total of 957 valid daily reports. The numbers of the valid reports at  
309 each phase were 162, 229, 195, 285, and 86 for the menstrual, follicular, peri-ovulatory, luteal, and  
310 premenstrual phases, respectively. One woman took emergency contraceptives on day 17 (she reported  
311 a positive result on LH test on day 13). Thus, her data after day 17 was not included in the study. In total,  
312 7.4% of the menstrual phase, 5.4% of the follicular phase, 7.1% of the peri-ovulatory phase, 12.0% of the  
313 luteal phase, and 15.7% for the premenstrual phase were missing. We used a repeated measures ANOVA  
314 to test whether the frequency of missingness varied across the phases. Repeated factors were the  
315 proportion of missingness per phase calculated for each participant (excluding the participant who  
316 dropped after day 17). Mauchly's test of sphericity indicated that the assumption of sphericity was

317 violated,  $\chi^2(9) = 25.03$ ,  $P = 0.003$ , thus a Greenhouse-Geisser correction was used. The result showed that  
318 the frequencies of missingness were not significantly differed across the five phases,  $F_{2,92, 93.51} = 2.21$ ,  $P =$   
319 0.09. Furthermore, although having missing data and unequal numbers of observations per individual  
320 could be an issue for traditional analysis of variance models, a linear mixed model is rather robust to  
321 missing data and unbalanced designs (reviewed in Gibbons et al. 2010).

322         The observed mean cycle length was 30.47 days, ranging from 24 to 40 days (excluding the  
323 participant who dropped after day 17). This was an average of 2.82 days longer than the self-reported  
324 cycle length. On average, women reported positive results on LH tests 7.13 days from the onset of  
325 scheduled test window. One participant (the one who took emergency contraceptives) had a positive test  
326 result on the day she started to use the test sticks. Thus, for this participant, the estimated fertile window  
327 had a lower accuracy (see INTRODUCTION). Exclusion of this woman's data did not alter the results and  
328 her data were retained.

329         Three women showed no LH surge despite taking LH tests on the specified dates. This might  
330 have been caused by a technical problem with the test, an anovulatory cycle, or an improperly scheduled  
331 test window. The last possibility seems probable as these women had a current cycle length 6 days longer  
332 or shorter than their previous one. For these women, LH surge date was estimated by a 15-day backward  
333 counting method (Exclusion of these women's data did not alter the results, thus they were kept in the  
334 analyses to increase statistical power). For the LH surge observed participants ( $n = 31$ , excluding the  
335 participant dropped after day 17), the mean interval between LH surge and the first day of subsequent  
336 menstruation was 14.19 days. However, this interval varied markedly from 6 to 21 days. Two women  
337 experienced LH surge 6 and 8 days respectively before their next menses and therefore had an unusually  
338 short luteal phase. These data indicate the potential for distortion when calculations of ovulation dates  
339 are based on calculations assuming a 28-day cycle length.

340 **Cycle effects on mood and the six relationship measures**

341 We tested a main cycle effect on the six relationship measures and mood in Model 1 and Model 2,  
342 respectively. Mood was also entered as a time-varying covariate in Model 3. According to the dual  
343 sexuality hypothesis, women partnered with less physically attractive men should show heightened sexual  
344 interest in extra-pair men and decreased attraction towards their partners during the peri-ovulatory  
345 phase compared to other phases. The commitment hypothesis predicts that women with higher level of  
346 mutual commitment should experience an increased level of attraction towards their partners and a  
347 decreased level of attraction towards other men during the peri-ovulatory phase relative to other phases.  
348 In Model 4, we examined whether physical attractiveness (PA) or mutual commitment (MC) moderated  
349 the effect of phase on the six relationship measures. Table 1 shows summaries of  $F$  tests for each of the  
350 fixed effects for Models 1, 3, and 4.

### 351 **Mood**

352 There was a significant main effect of cycle phase on mood (Model 2),  $F_{4, 366.11} = 6.74, P < 0.001$ .  
353 Pairwise comparisons showed that women scored significantly lower at the menstrual phase than at all  
354 other phases: the follicular ( $P < 0.001$ ); peri-ovulatory ( $P = 0.002$ ); luteal ( $P < 0.001$ ); and premenstrual  
355 phases ( $P < 0.001$ ). When mood was entered as a time-varying covariate (Model 3), mood had a  
356 significant effect and positively predicted obsession ( $b = 0.006, t_{879.37} = 4.56, P < 0.001$ ), care-receiving ( $b =$   
357  $0.01, t_{917.73} = 7.90, P < 0.001$ ), care-giving ( $b = 0.002, t_{914.55} = 6.75, P < 0.001$ ), separation distress ( $b =$   
358  $0.001, t_{906.47} = 3.05, P = 0.002$ ), and partner-directed desire ( $b = 0.02, t_{893.30} = 9.82, P < 0.001$ ). There was  
359 no significant association between mood and extra-pair sexual desire.

### 360 **Obsession**

361 The main effect of cycle phase was not significant (Model 1). When PA and MC were added to  
362 the model (Model 4), MC had a significant effect and positively predicted obsession ( $b = 0.41, t_{49.25} = 2.20,$   
363  $P = 0.03$ ). Controlling for PA and MC did not alter the results of the initial analysis. The main effect of PA,

364 interactions between PA and cycle phase and between MC and cycle phase had no significant effect on  
365 obsession.

### 366 **Care-receiving**

367 The main effect of cycle phase was significant (Model 1). An inspection of Figure 1 reveals that  
368 the lowest scores were in the peri-ovulatory and luteal phases. Pairwise comparisons showed that  
369 women reported significantly higher scores at the menstrual phase than at the follicular ( $P = 0.02$ ), peri-  
370 ovulatory ( $P = 0.01$ ), and luteal phases ( $P = 0.001$ ). Controlling for PA and MC (Model 4) did not alter the  
371 results of the initial analysis. The main effect of PA, MC, interactions between PA and cycle phase and  
372 between MC and cycle phase had no significant effect on care-receiving.

### 373 **Care-giving**

374 The main effect of cycle phase was not significant (Model 1). When mood was entered as a time-  
375 varying covariate (Model 3), a main effect of cycle phase on care-giving became significant. Mirroring the  
376 patterns found for care-receiving (see also Figure 1), women reported significantly higher scores at the  
377 menstrual phase than at the follicular ( $P = 0.02$ ), peri-ovulatory ( $P = 0.01$ ), and luteal phases ( $P = 0.01$ ).  
378 These results imply that the relation between cycle phase and care-giving initially appeared absent,  
379 because lower mood (which had a positive relation with care-giving) during the menstrual phase was  
380 suppressing the cycle phase effect (which was associated with higher care-giving during the menstrual  
381 phase). When PA and MC were entered to the model (Model 4), MC had a significant effect and positively  
382 predicted care-giving ( $b = 0.09$ ,  $t_{46.51} = 2.70$ ,  $P = 0.01$ ). Controlling for PA and MC did not alter the results  
383 of the initial analysis. The main effect of PA, interactions between PA and cycle phase and between MC  
384 and cycle phase had no significant effect on care-giving.

### 385 **Separation distress**

386 The main effect of cycle phase was not significant (Model 1). When PA and MC were added to  
387 the model (Model 4), MC had a significant effect and positively predicted separation distress ( $b = 0.13$ ,

388  $t_{39.96} = 3.11, P = 0.003$ ). Controlling for PA and MC did not alter the result of the initial analysis. The main  
389 effect of PA, interactions between PA and cycle phase and between MC and cycle phase had no significant  
390 effect on separation distress.

### 391 ***In-pair sexual desire***

392 Although Figure 1 shows a curvilinear relationship peaking at the peri-ovulatory phase, the main  
393 effect of cycle phase was not statistically significant (Model 1). Controlling for PA and MC (Model 4) did  
394 not change the results of the initial analysis. The main effect of PA, MC, interactions between PA and  
395 cycle phase and between MC and cycle phase had no significant effect on separation distress.

### 396 ***Extra-pair sexual desire***

397 The main effect of cycle phase was significant (Model 1). Figure 1 shows a curvilinear  
398 relationship peaking at the peri-ovulatory phase. Pairwise comparisons showed that compared to the  
399 peri-ovulatory phase, women reported significantly lower scores at the menstrual ( $P = 0.01$ ), luteal ( $P =$   
400  $0.01$ ), and premenstrual phases ( $P = 0.002$ ). Scores during the follicular phase were higher than at the  
401 premenstrual phase ( $P = 0.04$ ). A difference between the peri-ovulatory and the follicular phases was not  
402 significant ( $P = 0.14$ ). These results showed a mid-cycle rise for extra-pair sexual desire. When PA and MC  
403 were added to the model (Model 4), MC negatively predicted extra-pair sexual desire ( $b = -0.10, t_{73.50} = -$   
404  $2.71, P = 0.01$ ). Controlling for PA and MC did not alter the result of the initial analysis. The main effect of  
405 PA, interactions between PA and cycle phase and between MC and cycle phase had no significant effect  
406 on care-receiving.

### 407 **Comparisons between in-pair and extra-pair sexual desires**

408 Figure 1 shows that in-pair sexual desire was consistently higher than extra-pair sexual desire.  
409 We used paired-samples t-tests to compare in-pair and extra-pair sexual desires (untransformed) in each  
410 of the five phases. There were significant differences across all pairs: the menstrual phase,  $t(161) = 11.68,$

411  $P < 0.001$ ; the follicular phase,  $t(228) = 15.75$ ,  $P < 0.001$ ; the peri-ovulatory phase,  $t(194) = 13.88$ ,  $P <$   
 412  $0.001$ ; the luteal phase,  $t(284) = 16.57$ ,  $P < 0.001$ ; and the premenstrual phase,  $t(85) = 10.88$ ,  $P < 0.001$ .

### 413 **Moderation by SIA: A comparison of classification systems**

414 Haselton and Gangestad (2006) found support for the prediction of the dual sexuality hypothesis  
 415 that women partnered with men who had lower sexual-versus-investment attractiveness (SIA) would  
 416 show increased sexual desire towards other men at fertile relative to non-fertile phases. We re-analyzed  
 417 our data with SIA as a moderator in the two-phase classification scheme. No significant effect of phase  
 418 was found for any of the measures. Whereas our initial analysis revealed a cycle phase effect for care-  
 419 receiving and extra-pair sexual desire, neither of these was significant in the two-phase analysis,  $F_{1,32} =$   
 420  $0.50$ ,  $P = 0.49$ , and  $F_{1,32} = 0.43$ ,  $P = 0.52$ , respectively. However, replicating Haselton and Gangestad  
 421 (2006) findings, there was a significant interaction between cycle phase and SIA on extra-pair desire,  $F_{1,32}$   
 422  $= 5.36$ ,  $P = 0.03$ . In order to examine the cycle phase effect among participants whose partners had  
 423 higher and lower SIA, SIA was re-centered at one standard deviation (SD) above the mean (those with  
 424 relatively greater short-term attractiveness) and below the mean (those with relatively greater long-term  
 425 attractiveness). However, no cycle phase effect was found when partner SIA scores were one SD above  
 426 (marginal mean for a fertile phase = 1.37 and for a non-fertile phase = 1.67,  $F_{1,32} = 4.44$ ,  $P_{dir} = 0.02$ , the  
 427 unpredicted direction  $P > 0.01$ ) or below the means (marginal means for fertile phase = 1.51 and for non-  
 428 fertile phase = 1.34,  $F_{1,32} = 1.42$ ,  $P_{dir} = 0.12$ ). This did not support the prediction of the dual sexuality  
 429 hypothesis. It is also worth noting that in our recoded data, 14 out of 31 (45%) ovulation days detected  
 430 by LH surge were categorized by Haselton and Gangestad's (2006) criteria as 'non-fertile'.

431 When our five-phase classification scheme was applied, a cycle phase effect on extra-pair sexual  
 432 desire was significant,  $F_{2,66, 85,24} = 3.57$ ,  $P = 0.02$  (with Greenhouse-Geisser correction). Pairwise  
 433 comparisons showed that women scored significantly lower at the premenstrual phase than at the  
 434 follicular ( $P_{dir} = 0.01$ ) and peri-ovulatory phases ( $P_{dir} = 0.01$ ). The main effects of cycle on the other five

435 measures were not significant. The interaction between cycle phase and SIA was not significant for extra-  
436 pair sexual desire or for the other five measures.

## 437 **DISCUSSION**

### 438 **Lack of support for the commitment and dual sexuality hypotheses**

439 We found no support for the commitment hypothesis. In-pair sexual desire was not greater at  
440 the peri-ovulatory phase for women with high levels of mutual commitment, nor was extra-pair desire  
441 weaker. Eastwick and Finkel's (2012) test of the commitment hypothesis focused on intimate physical  
442 contact but this was chosen to represent a variable that "could plausibly strengthen (or, by its absence,  
443 weaken) intersexual cooperation" (p. 176). Our measures of obsession, care-giving, care-receiving, and  
444 separation distress can also be seen as fulfilling this function, without containing physical contact  
445 components. Indeed, women with higher levels of mutual commitment to their partner scored  
446 significantly higher on these measures. Nevertheless, mutual commitment did not moderate cycle phase  
447 effects for any of the measures.

448 Nor did we find evidence for the dual sexuality proposal. Although sexual desire for extra-pair  
449 men was higher during the peri-ovulatory phase compared to the menstrual, luteal, and premenstrual  
450 phases, partner physical attractiveness did not moderate this effect. Null results are not unprecedented.  
451 Of eight studies which have examined the moderating effect of partner attractiveness, six found support  
452 for increased extra-pair attraction at fertile versus non-fertile phases while one found support for reduced  
453 in-pair desire at ovulation (see Larson et al., 2012). It should be noted that, given the small sample size,  
454 there might have been insufficient variation in partner physical attractiveness and mutual commitment to  
455 detect the moderating effects. Indeed, most women in our study scored relatively highly in both variables.  
456 In this sense, we are unable to conclusively treat these null findings as replication failures.

457 Our sample size is relatively small, but we note that a sample size of  $N=38$  has 70% power to  
458 detect a true effect size of  $d = 0.5$  (Gangestad et al. 2016), given measurement accuracy of 85% for LH

459 tests and a between-phase correlation of  $r = 0.5$  (average correlations across the phases were all above  $r$   
460  $= 0.48$  for the six relationship measures). The loss of 5 participants reduced statistical power.  
461 Nevertheless, our sample was larger than some repeated-measures studies in paired-women that have  
462 reported positive results ( $N = 31$  in Gangestad et al. 2002;  $N = 24$  in Haselton and Gangestad 2006;  $N = 20$   
463 in Eastwick and Finkel 2012). Moreover, some studies reported large interaction effects between fertility  
464 and partner attractiveness on emotional closeness ( $N = 41$  and  $67$  in Study 1 and Study 2, respectively, in  
465 Larson et al. 2013) and on in-pair and extra-pair sexual attraction ( $N = 41$  in Larson et al. 2012). According  
466 to the conventional sample size recommendations for linear-mixed models, 957 daily reports for level-1  
467 unit and 35 participants for level-2 unit had an acceptable statistical power for level 1 and level 2  
468 predictors (Bell et al. 2010).

469 In summary, in-pair sexual desire did not peak at the peri-ovulatory phase, and levels of mutual  
470 commitment did not moderate the cycle phase effects in any of the six relationship measures. These  
471 findings did not support the commitment hypothesis. Our study also did not provide positive evidence for  
472 the dual sexuality hypothesis. Although extra-pair sexual desire was highest at the mid phases, in-pair  
473 sexual desire was significantly greater than extra-pair sexual desire throughout the cycle, and partner  
474 attractiveness did not moderate the cycle phase effects in both types of sexual desires. Our results could  
475 be more consistent with the spandrel hypothesis than the two adaptive explanations, suggesting that  
476 between-individual differences should be given more attention.

#### 477 **The main effect of cycle phase on the six relationship measures**

478 The main cycle phase effect was found for sexual desire for others, care-receiving, and care-  
479 giving. Regarding sexual desire measures, plots over the cycles of both in-pair and extra-pair sexual desire  
480 showed a mid-cycle rise (Figure 1). This is in line with a considerable body of work showing a peri-  
481 ovulatory peak in sexual desire (e.g., Roney and Simmons 2013), sexual fantasies, and sexual activity,  
482 including female-initiated sex (e.g., Gangestad et al., 2002). Although the plots showed a mid-cycle rise

483 for both types of sexual desire, the cycle phase effect was statistically significant only for extra-pair desire.  
484 This naturally prompts consideration of factors that might affect in-pair and extra-pair sexual desire. We  
485 discuss four possible considerations.

486           One possibility is mood. Indeed, mood varied significantly across the cycle, and positively  
487 predicted partner-directed emotional and sexual measures. However, it did not mediate the relationship  
488 between the main cycle phase effect and in-pair sexual desire.

489           A second possible explanation is that our results reflect demand characteristics (Orne et al. 2000),  
490 which refers to participants anticipating the purpose of study and altering their responses accordingly  
491 (and such a critique would also apply for other cycle studies). However, the fact that there was no  
492 significant difference between the follicular and peri-ovulatory phases makes this unlikely. If participants'  
493 knowledge of their positive LH test results or of the dual sexuality hypothesis could influence their levels  
494 of extra-pair sexual desire, we would expect to see a sudden increase in desire at the peri-ovulatory phase  
495 (i.e., when they read their positive results).

496           A third possibility to explain the null finding for the main cycle phase effect for in-pair sexual  
497 desire is that overall female hormonal levels moderated the size of cycle phase effects in a way consistent  
498 with the spandrel hypothesis (Havlíček et al. 2015a). This hypothesis implies that women with higher  
499 levels of estrogen are more physically attractive and show stronger preference for more masculine men.  
500 The hypothesis further predicts that ceiling effects on preferences occurs among such women, leading to  
501 a smaller cycle shift effect. If our participants' partner evaluations truly reflected their partners'  
502 attractiveness, the relatively higher mean scores for partner physical attractiveness found in our study  
503 imply that these women were paired with higher quality men. Thus, if our participants had relatively  
504 higher overall estrogen levels, it might have caused smaller cyclical variation in sexual desire for a partner.  
505 Future studies are required to examine how women's average hormone levels affect cycle shift effects.

506 A fourth possibility is that mechanisms underlying pair-bond relationships led to different main  
507 effects of cycle phase depending on the target of sexual attraction. Pair-bonded relationships have been  
508 hypothesized as a key aspect of human sexuality (e.g., Dixson 2009; Havlíček et al. 2015b; Emery  
509 Thompson and Muller 2016). Romantic love and sexual desire might be a part of mechanisms evolved to  
510 initiate and maintain pair-bond relationships with selected partners in order to increase offspring survival  
511 (Fisher 1998). Fisher (1998) hypothesized that romantic love plays a role of mate choice and leads  
512 individuals to focus their sexual desire towards a particular mate. Human females display extended  
513 sexuality (being sexually receptive or proceptive during non-fertile phases, see Gangestad and Thornhill  
514 2008). Some researchers have argued that extended sexuality was de-coupled from strict hormonal  
515 dependency (Havlíček et al. 2015b; Roney and Simmons 2016). In line with these arguments, the current  
516 study showed that the strength of women's sexual desire throughout the cycle was consistently higher for  
517 their romantic partners than for other men. Pair-bonding may be an adaptive aspect of female sexual  
518 desire that is uncorrelated with cyclical changes in hormones.

519 Regarding emotional measures, the main cycle phase effect was found only for care-receiving  
520 and care-giving. Care-receiving and care-giving were higher in the menstrual phase, compared to other  
521 mid-cycle phases (Figure 1). Although all women initiated their diaries on the first day of their menstrual  
522 cycle, an order effect is unlikely because the plots of both care-receiving and giving showed a curvilinear  
523 relationship with the lowest scores in the peri-ovulatory and luteal phases. (Order effects are also  
524 unlikely for extra-pair sexual desire as it followed a reverse U shape.) One possibility is that women seek  
525 more emotional connection during the menstrual phase when physical relationships with partners are  
526 less likely.

### 527 **Methodological considerations**

528 We found significant moderating effects of sexual-versus-investment (SIA) attractiveness when  
529 we employed Haselton and Gangestad's (2006) two-phase coding scheme. However, follow-up analyses

530 found no cycle phase effect when partner SIA scores were one SD above (those with relatively greater  
531 short-term attractiveness) or below the means (those with relatively greater long-term attractiveness).  
532 This suggests that the magnitude of the disparity between a partner's investment attractiveness and  
533 sexual attractiveness may not be particularly influential in driving women's extra-pair desire.

534           When our five-phase classification system was used, there was no evidence of moderation by SIA,  
535 although the main effect of cycle on extra-pair sexual desire that was found in our initial analysis  
536 remained. Our sample size was larger than Haselton and Gangestad's (2006,  $N = 24$ ) which increased our  
537 power to detect an effect. Our five-phase classification used LH tests to estimate ovulation which has a  
538 validity of between 0.8 and 0.9 (Gangestad et al. 2016). Gangestad et al.(2006) estimated ovulation by  
539 the backward counting method from a confirmed date of next menses, a method with an estimated  
540 validity of 0.66. This validity estimate drops to 0.64 when error associated with failure to detect  
541 anovulatory participants is added and is further compromised by the use of a shorter fertile window. The  
542 degree of estimation error can be substantial: In our sample, with the date of ovulation confirmed by LH  
543 surge, 45% of estimated ovulation days were misclassified by the backward counting method. One of the  
544 most evident differences between the analyses was the number of phases that were compared. An  
545 advantage of our five-phase scheme is that all daily data is included in the analysis whereas in the binary  
546 scheme the bulk of data is discarded which, aside from being wasteful, raises doubts about the objective  
547 basis on which data are selected (Harris et al. 2014; Gangestad et al. 2016). It is important to note that  
548 SIA was created based on sexual and investment attractiveness which were measured on different  
549 variables than in Haselton and Gangestad's original study, and this could contribute to inconsistent  
550 findings between our studies and the original. However, it is clear that results can vary markedly as a  
551 function of the classification system used to determine fertile and non-fertile phases.

552           On the basis of our data, we urge caution in the use of any technique that estimates ovulation on  
553 the basis of an assumed 28-day cycle. We found cycle lengths to vary between 24-40 days. With only 3

554 out of 34 participants experiencing a 28-day cycle, the forward counting methods is unlikely to accurately  
555 capture the date of ovulation. The backward counting method fares little better. The range of days  
556 intervening between LH surge and subsequent menses (6-21 days) was considerable. Our findings verify  
557 the argument of Gangestad et al. (2016) that the gold standard for future research is the use of daily  
558 measurement of estradiol and progesterone levels which can establish ovulation, in addition to their  
559 intrinsic value of examining the hormonal basis of cycle shift effects.

## 560 **CONCLUSIONS**

561 In closing, our work reveals a compelling need for further careful study of cycle effects on  
562 women's sexual desire, paying due attention to objectivity and accuracy of methods for determining cycle  
563 phases. We found significant problems with backward counting which was commonly used in earlier  
564 cycle studies. Moreover, our results raise potential issues in the dual sexuality and commitment  
565 hypotheses, and they also suggest that further investigation of the recent spandrel hypothesis may be  
566 fruitful. Future studies might also examine the role of cycle-independent factors on women's sexual  
567 desire.

568

569 **REFERENCES**

- 570 Barbieri RL. 2014. The endocrinology of the menstrual cycle. In: *Methods in Molecular Biology*. Vol. 1154. p.  
571 145–169.
- 572 Bell BA, Morgan GB, Schoeneberger, J. A. Loudermilk BL. 2010. Dancing the sample size limbo with mixed  
573 models: How low can you go? *SAS Global Forum*.
- 574 Cobey KD, Buunk AP, Pollet T V., Klipping C, Roberts SC. 2013. Men perceive their female partners, and  
575 themselves, as more attractive around ovulation. *Biol Psychol* 94:513–516.
- 576 Direito A, Bailly S, Mariani A, Ecochard R. 2013. Relationships between the luteinizing hormone surge and other  
577 characteristics of the menstrual cycle in normally ovulating women. *Fertil Steril* 99:279–285.
- 578 Dixson AF. 2009. *Sexual selection and the origins of human mating systems*. United Kingdom: Oxford University  
579 Press.
- 580 Eastwick PW, Finkel EJ. 2012. The evolutionary armistice: Attachment bonds moderate the function of  
581 ovulatory cycle adaptations. *Pers Soc Psychol Bull* 38:174–184.
- 582 Emery Thompson M, Muller MN. 2016. Comparative perspectives on human reproductive behavior. *Curr Opin*  
583 *Psychol* 7:61–66.
- 584 Fisher HE. 1998. Lust, attraction, and attachment in mammalian reproduction. *Hum Nat* 9:23–52.
- 585 Folstad I, Karter AJ. 1992. Parasites, bright males, and the immunocompetence handicap. *Am Nat* 139:603–622.
- 586 Gangestad SW, Haselton MG, Welling LLM, Gildersleeve K, Pillsworth EG, Burriss RP, Larson CM, Puts DA. 2016.  
587 How valid are assessments of conception probability in ovulatory cycle research? Evaluations,  
588 recommendations, and theoretical implications. *Evol Hum Behav* 37:85–96.
- 589 Gangestad SW, Thornhill R. 2008. Human oestrus. *Proc Biol Sci* 275:991–1000.

- 590 Gangestad SW, Thornhill R, Garver-Apgar CE. 2005. Women's sexual interests across the ovulatory cycle  
591 depend on primary partner developmental instability. *Proc Biol Sci* 272:2023–2027.
- 592 Gangestad SW, Thornhill R, Garver CE. 2002. Changes in women's sexual interests and their partner's mate-  
593 retention tactics across the menstrual cycle: Evidence for shifting conflicts of interest. *Proc Biol Sci* 269:975–  
594 982.
- 595 Gibbons RD, Hedeker D, DuToit S. 2010. Advances in analysis of longitudinal data. *Annu Rev Clin Psychol* 6:79–  
596 107.
- 597 Gildersleeve K, Haselton MG, Fales MR. 2014a. Do women's mate preferences change across the ovulatory  
598 cycle? A meta-analytic review. *Psychol Bull* 140:1205–1259.
- 599 Gildersleeve K, Haselton MG, Fales MR. 2014b. Meta-analyses and p-curves support robust cycle shifts in  
600 women's mate preferences: Reply to Wood and Carden (2014) and Harris, Pashler, and Mickes (2014). *Psychol*  
601 *Bull* 140:1272–1280.
- 602 Gonzales JE, Ferrer E. 2016. Efficacy of methods for ovulation estimation and their effect on the statistical  
603 detection of ovulation-linked behavioral fluctuations. *Behav Res Methods* 48:1125–1144.
- 604 Hahn AC, Fisher CI, Cobey KD, DeBruine LM, Jones BC. 2016. A longitudinal analysis of women's salivary  
605 testosterone and intrasexual competitiveness. *Psychoneuroendocrinology* 64:117–122.
- 606 Harris CR, Chabot A, Mickes L. 2013. Shifts in methodology and theory in menstrual cycle research on attraction.  
607 *Sex Roles* 69:525–535.
- 608 Harris CR, Pashler H, Mickes L. 2014. Elastic analysis procedures: An incurable (but preventable) problem in the  
609 fertility effect literature. Comment on Gildersleeve, Haselton, and Fales (2014). *Psychol Bull* 140:1260–1264.
- 610 Haselton MG, Gangestad SW. 2006. Conditional expression of women's desires and men's mate guarding  
611 across the ovulatory cycle. *Horm Behav* 49:509–518.

- 612 Havlíček J, Cobey KD, Barrett L, Klapilová K, Roberts SC. 2015a. The spandrels of Santa Barbara? A new  
613 perspective on the peri-ovulation paradigm. *Behav Ecol* 26:1249–1260.
- 614 Havlíček J, Cobey KD, Barrett L, Klapilová K, Roberts SC. 2015b. Greater precision, not parsimony, is the key to  
615 testing the peri-ovulation spandrel hypothesis: A response to comments on Havlíček et al. 2015. *Behav Ecol*  
616 26:1265–1267.
- 617 Havlíček J, Roberts SC, Flegr J. 2005. Women's preference for dominant male odour: Effects of menstrual cycle  
618 and relationship status. *Biol Lett* 1:256–259.
- 619 Larson CM, Haselton MG, Gildersleeve KA, Pillsworth EG. 2013. Changes in women's feelings about their  
620 romantic relationships across the ovulatory cycle. *Horm Behav* 63:128–135.
- 621 Larson CM, Pillsworth EG, Haselton MG. 2012. Ovulatory shifts in women's attractions to primary partners and  
622 other men: Further evidence of the importance of primary partner sexual attractiveness. Engelhardt A, editor.  
623 *PLoS One* 7:e44456.
- 624 McDonald JH. 2014. *Handbook of Biological Statistics*. 3rd ed. Baltimore, Maryland: Sparky House Publishing.
- 625 Münster K, Schmidt L, Helm P. 1992. Length and variation in the menstrual cycle—a cross-sectional study from a  
626 Danish county. *Brit J Obstet Gynaec* 99:422–429.
- 627 Orne MT, Whitehouse WG, Kazdin AE. 2000. Demand characteristics. In: Kazdin AE, editor. *Encyclopedia of*  
628 *psychology*. Washington, DC: American Psychological Association and Oxford University Press. p. 469–470.
- 629 Penton-Voak I. S, Perrett DI, Castles DL, Kobayashi T, Burt DM, Murray LK, Minamisawa R. 1999. Menstrual  
630 cycle alters face preference. *Nature* 399:741–742.
- 631 Pillsworth EG, Haselton MG. 2006. Male sexual attractiveness predicts differential ovulatory shifts in female  
632 extra-pair attraction and male mate retention. *Evol Hum Behav* 27:247–258.

- 633 Pillsworth EG, Haselton MG, Buss DM. 2004. Ovulatory shifts in female sexual desire. *J Sex Res* 41:55–65.
- 634 Rice WR, Gaines SD. 1994. “Heads I win, tails you lose”: Testing directional alternative hypotheses in ecological  
635 and evolutionary research. *Trends Ecol Evol* 9:235–237.
- 636 Roney JR, Simmons ZL. 2013. Hormonal predictors of sexual motivation in natural menstrual cycles. *Horm*  
637 *Behav* 63:636–645.
- 638 Roney JR, Simmons ZL. 2016. Within-cycle fluctuations in progesterone negatively predict changes in both in-  
639 pair and extra-pair desire among partnered women. *Horm Behav* 81:45–52.
- 640 Roney JR, Simmons ZL, Gray PB. 2011. Changes in estradiol predict within-women shifts in attraction to facial  
641 cues of men’s testosterone. *Psychoneuroendocrinology* 36:742–749.
- 642 Shimoda R. 2014. Dimensions of the heterosexual bond: Culture, personality and cycle effects. Doctoral thesis,  
643 Durham University.
- 644 Shimoda R, Campbell A, Barton RA. 2017. Data from: Women’s emotional and sexual attraction to men across  
645 the menstrual cycle. *Behav Ecol*. doi:10.5061/dryad.t5pr5
- 646 Tabachnick BG, Fidell LS. 2013. Using multivariate statistics. 6th ed. Boston, MA: Pearson.
- 647 Thornhill R, Chapman JF, Gangestad SW. 2013. Women’s preferences for men’s scents associated with  
648 testosterone and cortisol levels: Patterns across the ovulatory cycle. *Evol Hum Behav* 34:216–221.
- 649 Thornhill R, Gangestad SW. 2008. The evolutionary biology of human female sexuality. New York, NY: Oxford  
650 University Press.
- 651 Wegienka G, Baird DD. 2005. A comparison of recalled date of last menstrual period with prospectively  
652 recorded dates. *J Womens Health* 14:248–252.

- 653 Wilcox AJ, Dunson DB, Weinberg CR, Trussell J, Baird DD. 2001. Likelihood of conception with a single act of  
654 intercourse: Providing benchmark rates for assessment of post-coital contraceptives. *Contraception* 63:211–  
655 215.
- 656 Wilcox AJ, Weinberg CR, Baird DD. 1995. Timing of sexual intercourse in relation to ovulation - Effects on the  
657 probability of conception, survival of the pregnancy, and sex of the baby. *New Engl J Med* 333:1517–1521.
- 658 Wood W, Carden L. 2014. Elusiveness of menstrual cycle effects on mate preferences: Comment on  
659 Gildersleeve, Haselton, and Fales (2014). *Psychol Bull* 140:1265–1271.
- 660 Wood W, Kressel L, Joshi PD, Louie B. 2014. Meta-analysis of menstrual cycle effects on women’s mate  
661 preferences. *Emot Rev* 6:229–249.
- 662 Yang M, Gricar JA, Maruish ME, Hagan MA, Kornstein SG, Wallenstein G V. 2010. Interpreting premenstrual  
663 symptoms impact survey scores using outcomes in health-related quality of life and sexual drive impact. *J*  
664 *Reprod Med* 55:41–48.

## 665 TABLES

## 666 Table 1

667 Summaries of *F* tests for fixed effects on the six relationship measures in Models 1, 3, and 4.

Models	Obsession	Receiving	Giving	Separation	In-pair desire	Extra-pair desire
1 Cycle	0.83(0.51) <i>4,384.06</i>	<b>2.97(0.02)</b> <b>4,373.07</b>	1.53(0.19) <i>4,366.20</i>	1.45(0.22) <i>4,371.75</i>	2.19(0.07) <i>4,392.05</i>	<b>3.40(0.01)</b> <b>4,376.74</b>
3 Cycle	1.16(0.33) <i>4,377.09</i>	<b>5.62(0.001)</b> <b>4,371.50</b>	<b>2.64(0.03)</b> <b>4,360.02</b>	1.92(0.11) <i>4,361.75</i>	1.23(0.30) <i>4,380.48</i>	<b>2.91(0.02)</b> <b>4,374.48</b>
Mood	<b>20.83(0.001)</b> <b>1,879.37</b>	<b>62.37(0.001)</b> <b>1,917.73</b>	<b>45.53(0.001)</b> <b>1,914.55</b>	<b>9.32(0.002)</b> <b>1,906.47</b>	<b>96.50(0.001)</b> <b>1,893.30</b>	1.45(0.23) <i>1,920.44</i>
4 Cycle	0.86(0.49) <i>4,371.21</i>	<b>2.71(0.03)</b> <b>4,362.78</b>	1.45(0.22) <i>4,357.97</i>	1.35(0.25) <i>4,363.15</i>	2.22(0.07) <i>4,383.18</i>	<b>3.62(0.01)</b> <b>4,369.06</b>
PA	0.84(0.37) <i>1,32.56</i>	2.32(0.14) <i>1,32.18</i>	0.71(0.41) <i>1,32.34</i>	0.07(0.79) <i>1,32.06</i>	1.58(0.22) <i>1,32.56</i>	1.59(0.22) <i>1,33.06</i>
MC	<b>7.63(0.01)</b> <b>1,32.82</b>	2.99(0.09) <i>1,32.45</i>	<b>8.69(0.01)</b> <b>1,32.59</b>	<b>10.24(0.003)</b> <b>1,32.21</b>	0.50(0.49) <i>1,33.06</i>	<b>7.02(0.01)</b> <b>1,33.61</b>
PA×Cycle	0.68(0.60) <i>4,367.57</i>	1.14(0.34) <i>4,359.06</i>	0.89(0.47) <i>4,354.32</i>	0.43(0.79) <i>4,360.02</i>	0.79(0.53) <i>4,378.72</i>	1.89(0.11) <i>4,364.73</i>
MC×Cycle	1.44(0.22) <i>4,369.64</i>	1.40(0.23) <i>4,362.62</i>	0.54(0.71) <i>4,357.83</i>	0.97(0.43) <i>4,362.92</i>	0.82(0.52) <i>4,381.75</i>	1.37(0.24) <i>4,368.74</i>

668 PA, MC, and × represent physical attractiveness, mutual commitment, and interactions, respectively.

669 Reported numbers are *F*-values, *P*- values (in brackets), and *df* (in italic). Significant figures are shown in

670 bold.