Discounting for money, food, and sex, over the menstrual cycle

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Data and analysis code are available at <https://osf.io/xdy8f/>.

Abstract

Sexual desire, physical activity, economic, and other behaviours fluctuate over the menstrual cycle. However, we have an incomplete understanding of how preferences for smaller sooner or larger later rewards (known as delay discounting) change over the menstrual cycle. In this pre-registered, cross-sectional study, Bayesian linear and quadratic binomial regression analyses provide compelling evidence that delay discounting does change over the menstrual cycle. Data from 203 naturally cycling women show increased discounting (preference to more immediate rewards) mid-cycle, which is at least partially driven by changes in fertility. This study provides evidence for a robust and broad-spectrum increase in delay discounting (Cohen's h ranging from 0.1-0.4) around the fertile point in the menstrual cycle across multiple commodities (money, food, and sex). We also show, for the first time, that discounting changes over the menstrual cycle in a pseudo-control group of 99 women on hormonal contraception. Interestingly, such women increase their discounting of sex toward the end of the menstrual phase – possibly reflecting a prioritisation of bonding-related sexual activity before menstrual onset.

Keywords: menstrual cycle, women's health, delay discounting, time preference, hormonal contraception

Introduction

A wide variety of behaviours of naturally cycling females change over the menstrual phase. They experience higher sexual desire during ovulation (Gangestad et al., 2005), are more physically active (Fessler, 2003), and show an increase in flirting (Cantú et al., 2014) and competitiveness (Durante et al., 2014). Moreover, in the fertile window, females tend to wear more provocative clothes (Haselton et al., 2007) and display stronger preference for males with characteristics associated with genetic quality, such as symmetry and masculinity (Gildersleeve et al., 2014).

This paper focuses upon how delay discounting (the preference towards either smaller sooner rewards versus larger later rewards) changes over the menstrual cycle. The first study to examine this in naturally cycling women showed that mid-cycle, women displayed *lower* preference for immediate hypothetical monetary rewards (Smith et al., 2014). That is, around peak fertility, preferences would shift away from short term rewards toward larger later monetary rewards. A cross-sectional study of naturally cycling women was conducted by (Lucas & Koff, 2017), but their data showed the exact opposite pattern. Mid-cycle women around peak fertility displayed *stronger* preference for immediate hypothetical monetary rewards. The present study aims to resolve these conflicting findings and to expand our knowledge in both naturally cycling women (NC) and those on hormonal contraception (HC).

Phases of the menstrual cycle

For naturally cycling (NC) females a typical menstrual cycle comprises of two predominant phases, the Follicular Phase (FP) and the Luteal Phase (LP; see Table 1). The FP starts at day one of the cycle (the first day of menses) and varies in length between one and two weeks, typically. The FP can also be broken into two phases, early follicular (EF) and late follicular (LF). In the EF, sex hormone levels are relatively low and stable, in the LF the sex hormone levels rise before ovulation occurs. Females are fertile from the day of ovulation (LF) for up to two days after making this the fertile part of the menstrual cycle. Ovulation is the day that the egg is released and marks the end of the FP (and the LF subphase of the FP). Then, the LP begins with sex hormone levels decreasing sharply before oestrogens and progesterone rise and fall over the phase, which is approximately two weeks in length (Hampson, 2020).

Table 1: Characteristics of menstrual cycle phases

Phase	Days (approximately)	Sex hormone levels
Early FP	1-7	Oestrogens: low, stable Progesterone : low, stable Follicle Stimulating Hormone: low, stable Luteinizing Hormone: low, stable
Late FP	7-13	Oestrogens: increases, peaks Progesterone: low, stable Follicle Stimulating Hormone: increases, peaks Luteinizing Hormone: increases, peaks
Ovulation	14	Oestrogens: decreases Progesterone: low, stable Follicle Stimulating Hormone: low, stable Luteinizing Hormone: decreases
LP	15-28	Oestrogens: increases, decreases Progesterone: increases, peaks, decreases Follicle Stimulating Hormone: decreases, low, stable Luteinizing Hormone: decreases, low, stable

Why might behaviour vary over the menstrual cycle?

Evolutionary accounts offer an approach with the potential to explain why (rather than just how) behaviours may change as they do. Humans and other primates are unique among the animal kingdom for having evolved psychological control over sexual behaviours, such that we can moderate these behaviours in conjunction with psychological impulses (Wallen & Zehr, 2004). Fluctuating hormones, however, still influence behaviour in our species and in our primate relatives. The ovulatory shift hypothesis (Thornhill & Gangestad, 2008) states that alterations in women's motives, thoughts and behaviours across the menstrual cycle are based on hormonal changes. Specifically, female behaviours during the fertile window (ovulation) are motivated by increased conception opportunity (Gildersleeve et al., 2014). Shifts in time preference towards immediate rewards during the most fertile window could help acquire essential supplies to improve attractiveness, reproductive success, and outperform potential rivals. Research on economic choice behaviours support this view: During peak fertility, women tend to spend more money on clothing

(Saad & Stenstrom, 2012), pick products that boost appearance (Durante et al., 2011; Haselton et al., 2007), withdraw more money from attractive rather than less attractive females in a competitive setting (Lucas & Koff, 2013), and seek to obtain sources that elevate their social status (Durante et al., 2014).

The present study

A variety of behaviours fluctuate over the menstrual cycle, but in terms of discounting we have conflicting findings between Smith et al., (2014) and Lucas & Koff (2017). Our goal is to move towards resolving this uncertainty by conducting a cross-sectional study of women, assessing their temporal discounting. We make three important advances in our approach. Firstly, we not only characterise discounting in NC women, but also use women on hormonal contraception (HC) as a pseudo-control group. This is a relatively rare practice, but we believe it is important. If behaviours change due to changes in gonadal hormone levels, HC would interrupt this cyclic variation (Erol & Karpyak, 2015), which may subsequently affect behaviour (Warren et al., 2021). Secondly, rather than focussing only on preference for monetary rewards, we also evaluate discounting for food and sex. There is convincing evidence that time and risk preferences are sensitive to the kind of reward being considered (Charlton & Fantino, 2008; Rosati & Hare, 2016), so characterising any changes in discounting for food, money, and sex can help constrain theorising. Thirdly, while it is common to examine menstrual phase categorically (e.g., EF, LF, LP), this approach discards temporal information which may help characterise changes in discounting over the menstrual cycle. We analyse discounting behaviour as a function of both categorical menstrual phase *and* by the continuous measure of days since menstrual onset.

We pose the following research questions: 1) Does cycle phase (EF, LF, LP) influence delay discounting across food, sex, and money commodities in NC women; 2) Does discounting vary non-linearly over the menstrual cycle, and does that differ by group (NC/HC) for each of the 3 commodities; 3) Does discounting vary linearly as a function of fertility and group (NC/HC) for each of the 3 commodities?

Methods

Participants

We recruited 413 menstruating individuals over 18 years of age to an online questionnaire through social media posts. We believe participants were intrinsically motivated to provide accurate responses as the study was not incentivised - nevertheless we applied strict (pre-registered) exclusion criteria. A total of 13 participants failed 1 or more of 5 attention checks and were excluded. A further 6 were excluded who indicated they were pregnant. 43 participants were excluded for indicating ‘totally irregular’ menstrual cycle lengths, defined as more than 7 days difference. Finally, 21 participants were excluded for having cycle lengths of greater than 40 days (*Periods and Fertility in the Menstrual Cycle* - NHS, 2019). This resulted in a total of 330 participants after our pre-registered exclusion criteria. We applied additional exclusion criteria resulting in removal of 25 participants whose days since menstrual onset measure was invalid (negative), or greater than 40 days. This was higher than expected because days since menstrual onset was calculated from the data of questionnaire completion and date of last menstruation - the latter contained dates that were unclear or very far in the past. We also recorded height and weight for a different hypothesis not examined in this study, but we used this data to remove 3 outlier participants with weight less than 40kg. The final dataset contained 302 participants who were grouped into naturally cycling (NC) or hormonal contraception (HC) groups using pre-registered criteria. We categorised 203 participants into the NC group based on their lack of a positive response to being on hormonal contraception. We categorised 99 participants into the HC group who specified their use of hormonal contraception – the type of hormonal contraception was not measured.

Procedure

The study received ethical approval from the University Research Ethics Committee of the University of Dundee. The study, measures, exclusion criteria, and analyses, were pre-registered to the Open Science Framework <https://osf.io/vwr6s/>. The questionnaire consisted of three sections: the demographic information, menstrual cycle details, and three independent tasks to investigate delay discounting behaviours for money, food and sex, respectively. A total of 5 attention check questions were interspersed throughout the questionnaire.

Measures

Participants were asked a range of questions: age, has your body menstruated in the last 60 days (yes/no), gender (Female, Male, Non-binary, prefer not to say, other), height, weight, ethnicity (Asian, Black/African/Caribbean, Mixed/Multiple ethnic groups, Caucasian/White, Prefer not to say), sexual orientation (Asexual, Bisexual, Homosexual/Gay/Lesbian, Heterosexual/Straight, Questioning or unsure, Prefer not to say), relationship status (single, casual, serious, married), and relationship type (monogamous, polygynous, polyamorous, open relationship).

Further questions were asked relating to the menstrual cycle, hormonal contraception, and other hormone related factors: 1) Regularity in menstrual cycle length (Perfectly regular (the same length between cycles), Regular (2-4 days difference), Irregular (5-7 days difference), Totally irregular (more than 7 days difference); 2) Length of menstrual cycle (days); 3) Days since menstrual onset – calculated by date of last onset minus questionnaire completion date; 4) Tracking method (tracking app, calendar, temperature check, cervical mucus observation, no method, other); 5) Contraception in last 3 months (yes/no); 6) Contraception type (hormonal/non-hormonal/not applicable); 7) Are you taking hormonal medication (other than contraception) which interferes with menstruation?; 8) Have children (yes/no); 9) Pregnant or breastfeeding(yes/no); 10) Planning on pregnancy in next 6 months (yes/no).

Estimation of fertility

Fertility was estimated using the lookup table method of Wilcox et al. (2001) and is computed from the day of cycle for those classified as having regular vs irregular cycle lengths. This fertility measure provides a probability of clinical pregnancy following a single act of unprotected intercourse.

Discounting tasks

Delay discounting tasks were created by applying an elicitation by multiple price list approach (Andersen et al., 2006). Raw response data was scored simply as the number of immediate choices.

Discounting of money. Participants made a series of choices between immediate amounts of money now £[95, 90, 80, 70, 60, 50, 40, 30] and £100 in 1 day. These were presented simultaneously in a list of questions with one example being “Would you prefer £95 now or £100 in 7 days?”. After responding, the

same set of questions were posed, incrementing to the next delay in the sequence of 1, 2, 7, 30, 180, 365 days.

Discounting of food. Participants selected between an immediate number of hypothetical bites (9-1) or 10 bites of food after a delay. Delays ranged in the following order: 1 hour, 2, 4, 6, 8, and 10 hours. The example question: "Would you prefer 5 bites of food now or 10 in 1 hour?" After the food discounting task, two further questions were asked: "When did you last eat?" (less than 10 minutes ago, 10 > 30 minutes ago, 30 minutes > 1 hour ago, 1 > 2 hours ago, more than 2 hours ago); and "What kind of food were you thinking about?" (healthy food, sweet food, fatty food, other – please specify), but these responses were not analysed.

Discounting of sex. Participants selected between hypothetical immediate lower-quality sex (<10/10) or delayed 10/10 high-quality sex – delays ranged from 1 hour, 2, 6, 24, 48 to 72 hours. An example question was: "Would you prefer 6/10 sexual activity now or 10/10 in 1 hour?". Questions were presented simultaneously as a list, and each consecutive list incremented the delay to the next in the sequence. At the beginning of the sex-discounting task, participants were asked "when was the last time you had sexual activity?" (less than 24 h ago, 1 day > 4 days ago, 4 > 7 days ago, 2 weeks ago, more than 2 weeks ago, prefer not to say).

Analyses

Because our primary outcome measure (discounting behaviour) is a count (number of immediate choices selected) out of n total choices, then the relevant form of Generalized Linear Modelling is binomial regression with a Logistic link function. The likelihood function is therefore $y_i \sim \text{Binomial}(n, \epsilon + (1 - 2\epsilon) \cdot \text{InverseLogistic}(\mu_i))$, which can be thought of as describing the probability of having observed y_i 'successes' (i.e. immediate choices) for participant i , out of n trials. $\text{InverseLogistic}(\mu_i)$ is the probability of success, where μ_i is the output of a linear model. The inverse logistic function corresponds to a logistic link function and maps μ_i to the range 0-1, which is valid for probabilities. The term $\epsilon + (1 - 2\epsilon)$ implements a 'lapse rate' which limits the probability of observing immediate choices to a minimum of ϵ

and a maximum of $1 - \epsilon$ (where we set $\epsilon = 0.01$). This is a commonly used method to avoid data being seen as infinitely unlikely if the model predicts probabilities of 0 or 1.

For the categorical analysis by menstrual phase, the linear model is $\mu_i = \beta[\text{phase}_i]$ where β is a vector of 3 values (one for each group) and phase_i indexes into the appropriate group that participant i is in. For the quadratic binomial regressions of discounting as a function of days since onset, we have $\mu_i = \beta_0 + \beta_1 \text{days}_i + \beta_2 \text{days}_i^2$. For evaluating discounting as a function of fertility, we use a linear model for the NC women, $\mu_i = \beta_0 + \beta_1 \text{fertility}_i$. And for the HC women we fit an intercept-only model, $\mu_i = \beta_0$, because fertility is held approximately constant. We used Normal priors over the β parameters, cantered on zero with high standard deviations as the data were not z-scored. This means the priors were broadly uninformative, meaning that the resulting posterior distributions over regression coefficients are primarily determined by the data.

We conducted Bayesian binomial regressions, evaluating the posterior distributions over the model parameters given the observed data, $P(\beta|x, y)$ where x is either the phase, fertility score, or days since onset, and y is the number of immediate choices made (for either money, food, or sex rewards). Practically, these posterior distributions were evaluated using PyMC3 (Salvatier et al., 2016), the dominant probabilistic programming framework in the Python programming language. All analysis code is available in online supplementary material (see Appendix).

Because this study was largely exploratory in nature, we focus on posterior beliefs about model parameters, effect sizes, and 95% credible intervals, as opposed to explicit hypothesis testing via Bayes Factors. Note that 95% *credible* intervals correspond to the region which we believe has 95% chance of containing the true value, unlike Frequentist 95% *confidence* intervals.

Results

Descriptive statistics

The participant composition, after exclusion, is shown in Table 2. The menstrual cycle lengths reported had a bimodal distribution, indicating that some participants reported duration of menstruation and

the majority reporting length of the menstrual cycle - we do not use this variable as a predictor, nor for exclusion and do not analyse it further. The mean number of days bleeding reported was 5.2, with a standard deviation of 1.8 days - there was one outlier who reported 28 days bleeding, who was not excluded. The majority of women 167 (55.3%) tracked their menstrual cycle with an app, 51 (16.9%) used a calendar, 11 (3.6%) used a range of other methods, while 73 (24.2%) did not use any tracking method. The mean reported BMI was 24.5 (median of 23.7) with a standard deviation of 5.6 kg/m².

Table 2: Demographic characteristics

Trait	Category	Number, Proportion
Sexuality	Heterosexual	227, 75.2%
	Bisexual	46, 15.2%
	Homosexual	10, 3.3%
	Asexual	9, 2.8%
	Unsure	5, 1.7%
	Prefer not to say	5, 1.7%
Relationship status	Serious	138, 45.7%
	Single	88, 29.1%
	Married	60, 19.9%
	Casual	16, 5.3%
Relationship types	Monogamous	271, 89.7%
	Prefer not to say	8, 2.7%
	Open relationship	3, 1%
	Polyamorous	3, 1%
	Polygamous	2, 0.7%
Ethnicity	Caucasian	257, 85.1%
	Asian	16, 5.3%
	Prefer not to say	12, 4%
	Mixed	9, 3%
	Black/African/Caribbean	8, 2.7%
Gender identity	Female	296, 98%
	Non-binary	3, 1%
	Male	2, 0.66%
	Prefer not to say	1, 0.33%
Menstruation duration	Perfectly regular	83, 27.5%
	Regular (2-4 days difference)	192, 63.6%
	Irregular (5-7 days difference)	27, 8.9%

Exploratory results

We examined whether we could replicate the results of Lucas & Koff (2017) for monetary reward and whether this result generalised to food and sex commodities. Figure 1 (top) shows mean discounting behaviour as a function of ovulatory cycle phase. Because we are not interested in comparing discounting behaviour across commodities, 3 independent Bayesian binomial regression models were used to estimate the mean number of immediate rewards chosen for each phase. We used the same method of calculating ovulatory phase as Lucas & Koff (2017): Early Follicular: ≤ 7 days since onset; Late Follicular: 8-15 days since onset; Luteal: 16-28 days since onset. Figure 1 (top row) shows a common pattern across all 3 commodities - the proportion of immediate choices increases in the fertile LF phase which then partially drops back down in the LP. Posterior distributions indicate unambiguous evidence of increases in the proportion of immediate choices from EF to LF (Figure 1, middle row). The Cohen's h effect sizes for money (0.12, $CI_{95\%}$: 0.064, 0.17), food (0.15, $CI_{95\%}$: 0.095, 0.20), and sex (0.37, $CI_{95\%}$: 0.32, 0.43) are "small" (Cohen, 1988). Posterior distributions of effect sizes from LF to LP (Figure 1, bottom row) also show strong evidence for a slight decrease, but not a return to levels in EF. Cohen's h effect sizes are "small" for money (-0.061, $CI_{95\%}$: -0.11, -0.011), food (-0.099, $CI_{95\%}$: -0.15, -0.048), and sex (-0.14, $CI_{95\%}$: -0.19, -0.085).

Figure 1. Mean discounting behaviour for naturally cycling women grouped by phase of the ovulatory cycle, for each of the 3 commodities (top row). The y-axis represents the probability of choosing immediate rewards as computed through Bayesian binomial regression. For example, a value of 0.2 equates to 20%. Error bars represent 95% Bayesian credible intervals. Distribution plots (middle, bottom rows) show posterior distributions over the effect size, Cohen's h . Mean and 95% credible intervals are rounded to 2 significant figures.

Confirmatory results

While converting days since menstrual onset into categorical phases is common, it does discard information about where women are within that phase. We build upon the previous results with the hope of gaining further insight into the time-course of discounting changes over the menstrual cycle.

Discounting as a function of days since onset. In our first pre-registered analysis, we tested for non-linear relationships of discounting as a function of days since onset. Figure 2 shows the results of our quadratic binomial regression analyses. The lines and shaded regions show the posterior mean and 95% credible intervals in the mean probability of choosing the immediate rewards. These clearly demonstrate quadratic relationships in all cases - an observation supported by the posterior distributions of regression

coefficients being credibly non-zero (see Table 3) for all linear and quadratic terms. That is, none of the 95% credible intervals overlap with zero. All the intercept terms β_0 were also credibly non-zero, although this is less theoretically interesting as β_0 is simply the intercept term which shifts the baseline proportion of immediate choices up or down.

Figure 2. Mean discounting behaviour as a function of days since onset for naturally cycling (NC) and hormonal contraception (HC) groups, resulting from Bayesian quadratic binomial regression analyses. Solid lines represent posterior means, and the shaded regions represent 95% credible intervals in the mean probability of choosing the immediate reward. Note: the functions may not look exactly quadratic because the quadratic term is passed through the Inverse Logistic function to constrain probabilities between 0-1.

Table 3. Summary statistics of the posterior distributions over all (unstandardised) regression coefficients for the quadratic binomial regressions shown in Figure 2. Plots of the posterior distributions of all parameters are available in the online Supplementary Materials. HDI = highest density intervals.

Parameter	Group	Commodity	Mean	SD	Lower 95% HDI	Upper 95% HDI
β_0	HC	Money	-1.216	0.075	-1.360	-1.067
β_0	HC	Food	-0.587	0.069	-0.722	-0.451
β_0	HC	Sex	-1.904	0.104	-2.109	-1.705
β_0	NC	Money	-1.064	0.056	-1.175	-0.953
β_0	NC	Food	-0.210	0.051	-0.309	-0.110
β_0	NC	Sex	-2.951	0.100	-3.140	-2.748
β_1	HC	Money	0.077	0.011	0.056	0.099
β_1	HC	Food	0.119	0.010	0.099	0.141
β_1	HC	Sex	-0.035	0.015	-0.066	-0.007
β_1	NC	Money	0.037	0.009	0.020	0.053
β_1	NC	Food	0.037	0.008	0.022	0.052
β_1	NC	Sex	0.169	0.014	0.141	0.197
β_2	HC	Money	-0.002	0.000	-0.003	-0.001
β_2	HC	Food	-0.004	0.000	-0.004	-0.003
β_2	HC	Sex	0.002	0.000	0.001	0.003
β_2	NC	Money	-0.001	0.000	-0.002	-0.001
β_2	NC	Food	-0.001	0.000	-0.002	-0.001
β_2	NC	Sex	-0.005	0.000	-0.006	-0.004

Discounting as a function of fertility. Having found evidence for change in discounting over the cycle, we test the idea that this can (at least in part) be accounted for by changes in fertility over the cycle. So our second pre-registered analysis explored linear relationships between discounting behaviour and fertility (see Figure 3). If fertility is an important factor, then we would expect to find a linear relationship

between fertility and discounting behaviour for NC women. This would not apply to HC women, whose fertility is held approximately constant over time. Figure 3 shows intercept fits to HC women and linear regression fits to NC women. The posterior distributions over the slope parameter for the NC women are all credibly positive: for money it is 2.00, $CI_{95\%}$: 0.89, 3.18, for food it is 2.15, $CI_{95\%}$: 1.11, 3.34, for sex it is 5.48, $CI_{95\%}$: 4.08, 6.85. We calculated the Cohen's h effect sizes comparing the probability of choosing the immediate reward at the lowest and highest fertility levels, resulting in small effect sizes for money (0.069), food (0.065), and sex (0.76).

Figure 3. Mean discounting behaviour as a function of fertility for naturally cycling (NC) and hormonal contraception (HC) groups, obtained from Bayesian binomial regression models. NC women were fitted

with a slope and intercept model while HC women were fitted with an intercept only model, as fertility is held constant in the HC group.

Discussion

The present study aimed to address three questions. Firstly, we explored whether cycle phase (EF, LF, LP) influence delay discounting across the food, sex and money commodities in NC women (see Figure 1). Secondly, by assessing non-linear trends over the cycle for both NC and HC women, we found evidence for a quadratic trend for all commodities and both groups (see Figure 2). For the NC group, immediate choices increased from the EF to the LF (when most fertile) and then decreased to the LP across all commodities. The same pattern occurred for the HC group for money and food, however, the opposite pattern was shown for sex. Thirdly, we explored whether change in discounting across the cycle could (at least partially) be explained by changes in fertility. This does seem to be the case, as NC women showed a linear increase in immediate choices across all commodities as a function of fertility (see Figure 3).

The results summarised in Figure 1, are in line with those of Lucas & Koff (2017). Similar to Lucas & Koff's (2017) results, the probability of choosing immediate rewards increased from the EF to the LF, followed by a drop again in the LP, however in contrast to their findings, they remained somewhat elevated compared to the EF phase. Our results go further however, in that we show this pattern of behaviour generalises across all the commodities tested - money, food, and sex.

Discounting for money, food, and sex changes over the menstrual cycle for NC women, with more immediate choices being made on average around the most fertile LF phase (see Figure 2) is in line with the Ovulatory Shift Hypothesis. NC individuals would theoretically be expected to optimise resources and immediate choices when conception is at a higher risk (da Matta et al., 2013; Gildersleeve et al., 2014). Additionally, there was support that some of the variation in discounting behaviour in NC women over the menstrual cycle can be attributed to fertility (see Figure 3). Women who are NC are, on average, are more likely to choose immediate rewards at more fertile points in their cycle. NC women should choose immediate rewards at peak fertility, especially sex, as they would be anticipating offspring. Biologically, we know that hormone levels during this point lead to increased impulsivity which is consistent with this

result (Diekhof, 2015). For medium/high fertility levels, NC women are more likely to choose immediate lower quality sex than HC women. This inspires the hypothesis that because HC bodies are more hormonally similar to pregnancy than NC bodies, perhaps higher quality sex may be preferred as a method of partner bonding over an immediate but low-quality opportunity for intercourse and conception.

Interestingly, HC women discount more for money and food, only matched by NC women at peak fertility. The rise and fall of immediate choices for money and food was even more exaggerated compared to NC women. Most hormonal contraceptives function through simulating pregnancy. Therefore, HC individuals would need resources for offspring. Again, biologically this is plausible as HC hormone levels are most similar to the fertile point of the cycle. The exception to the above was discounting of sex by HC women. The probability of choosing immediate low-quality sex over delayed high-quality sex seemed to be approximately stable but with an increase toward the end of the menstrual cycle. This could be noise that may disappear in a study with more participants or using a longitudinal design. If not, a speculative hypothesis (to be tested in a future study) would be that it represents a desire to have sex before the next menstrual period begins. Given there is no risk of conception to HC individuals, they may be opportunistically choosing intercourse later in the cycle (LP) to avoid having intercourse during menstruation. Vaginal intercourse during menstruation has medical implications, including an increased risk of Sexually Transmitted Infections (STIs) and endometriosis (Mazokopakis & Samonis, 2018). Another plausible explanation for this result could be that HC can lead to increased libido as it improves PMS and studies have shown increased female-initiated activity later in the pill cycle (LP; (Guillebaud, 2017).

However, the present study did not compare the different types of hormonal contraception. This is problematic as the different types have varying hormonal effects (Hampson, 2020). Further studies should include a HC sample when investigating the menstrual cycle and account for the type and duration of contraceptive use. Both the present study and Lucas & Koff (2017) used cross-sectional designs which is problematic as menstrual cycles vary between females and as such a within-subjects design would be beneficial for future research. While the Cohen's *h* effect sizes are 'small', this should be interpreted with

extreme caution – they are entirely unlike Cohen’s d effect sizes, taking no account of the difference normalised by the degree of spread, nor the same size. As such, readers should decide for themselves if a change from ~7.5% to ~20% immediate low quality over delayed high quality sex choices is a behaviourally relevant effect. Although we do not make strong claims based on our data about the exact shape of this change over the menstrual cycle, nor about the location of the peak of immediate choices. The present study used quadratic regression which has been used before in tracking how variables change over the menstrual cycle (Kuukasjärvi et al., 2004). Future research should continue with this non-linear form of analysis over days (not categorical phases) to encompass changes across the menstrual cycle phases as other analyses may fail to capture its cyclical nature.

Conclusion

Our findings from 203 NC and 99 HC women, demonstrate that changes in discounting behaviour can be detected in a cross-sectional study design. By including HC women as a control group and analysing how discounting changed (using a quadratic model) over the menstrual cycle, we found evidence for changes in discounting behaviour in both groups. Because of the exploratory, and cross-sectional, nature of our data we do not make strong claims about the precise nature of these changes. But we believe that these results can motivate future exploration and hypothesis testing into the nature of these changes for both NC and HC women. We did however find evidence that some of this variation over the menstrual cycle in NC women can be accounted for by the rise and fall in fertility, which is in line with evolutionary shift hypotheses (Gangestad et al., 2005; Gildersleeve et al., 2014). Longitudinal designs are perhaps best suited for the study of behaviour change over the menstrual cycle (Warren et al., 2021) - the large individual variation in discounting behaviour (for example) could be controlled for focusing on *within-participant change* across the menstrual cycle.

Appendix

Data and code availability

Data and code are available at <https://osf.io/xdy8f/>.

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