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# Cooperative preferences fluctuate across the menstrual cycle

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**Abstract**

Social Value Orientation (SVO) refers to an individual's preference for the division of resources between the self and another person. Since evidence suggests that hormones influence several facets of human social behavior, we asked whether SVO might fluctuate across the female menstrual cycle. Using self-report data obtained in two independent online studies, we show that cooperative preferences, as indexed by SVO, are indeed significantly more prosocial in the early follicular compared to the midluteal phase in naturally ovulating women. Furthermore, when estimating hormonal variations from norm data, we found estradiol, but not progesterone or testosterone, to be a significant predictor of SVO across the menstrual cycle in both studies, with a negative correlation. Our findings provide evidence that the willingness to cooperate varies across the natural female menstrual cycle and highlight the potential of investigating psychological effects of ovarian sex hormones.

Keywords: menstrual cycle, social value orientation, cooperative preferences, prosociality, ovarian hormones.

## 1 Introduction

People engage in a variety of cooperative and prosocial behaviors, ranging from helping family members and friends to donating money, goods, and even blood or bone marrow to unrelated strangers. This willingness to share resources with others differs between individuals and can be conceptualized as a person's other-regarding preferences, commonly termed *Social Value Orientation* (*SVO*; Van Lange, 1999). In approximation of a behavioral observation, SVO is typically measured in a series of decomposed games, where participants, depending on their preferences, allocate higher or lower fictitious amounts of money to themselves and another person (e.g., *SVO Slider Measure*; Murphy, Ackermann & Handgraaf, 2011). The two most prominent preferences found with this procedure are the prosocial one (aiming to maximize the sum of resources for the self and the other), and the individualistic one (striving to maximize the resources for the self regardless of the outcome for the other).

SVO has been shown to be a highly efficient and reliable measure and a good predictor of diverse forms of cooperative behavior both in laboratory and real-life settings (reviewed in Bogaert, Boone & Declerck, 2008), consistent with the assumption of a domain-general individual disposition towards cooperation (Peysakhovich, Nowak & Rand, 2014). For instance, SVO predicts cooperation in interactive multiplayer games from behavioral economics, such as sharing in the dictator game (Kinnunen & Windmann, 2013), cooperation decisions in the prisoner's dilemma game (Murphy et al., 2011), and reciprocation in the trust game (van den Bos, van Dijk, Westenberg, Rombouts & Crone, 2009). In real life, SVO predicts the inclination to commute by public transportation rather than by car (Van Vugt, Meertens & Van Lange, 1995), the willingness to engage in proenvironmental behaviors (Joireman, Lasane, Bennett, Richards & Solaimani, 2001), and positive attitudes in negotiations (De Dreu & Van Lange, 1995). As a consequence, SVO has become one of the most widely used measures to assess stable individual differences in cooperative preferences in social and personality research. Nonetheless, a recent study demonstrated that a single administration of the serotonin-norepinephrine releasing agent 3,4-Methylenedioxymethamphetamine can alter SVO substantially (Hysek et al., 2014), suggesting that similar to other personality factors such as anxiety, sensitivity to punishment/reward, and empathy (e.g., Hysek et al., 2014; Kent, Coplan & Gorman, 1998; van Honk et al., 2004), SVO might have a state component that is sensitive to transient neurobiological variation. This raises the possibility that cooperative preferences as measured by SVO might also be influenced by endogenous fluctuations in neuromodulation, but as of yet this question has not been examined.

Generally, one important modulator of the willingness to cooperate seems to be sensitivity to hormonal variation, as indicated by studies on the genetic variations of hormone receptors (e.g., Israel et al., 2009; Tost et al., 2010). Fur-



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ther evidence from administration studies confirms that hormones influence diverse facets of human cooperation behavior. For instance, oxytocin has been demonstrated to affect donations to charity (Barraza, McCullough, Ahmadi & Zak, 2011) and the choice (not) to attempt to gain money at the expense of others (De Dreu, Scholte, van Winden & Ridderinkhof, 2015), whereas testosterone was shown to influence generosity when repaying trust (Boksem et al., 2013). However, administration studies induce relatively unnatural stimulations with regards to dosage, time-point, and dynamics of absorption (for a more detailed discussion of these limitations, see Bos, Panksepp, Bluthé & van Honk, 2012; Churchland & Winkielman, 2012), leaving open the question of whether hormonal fluctuations within the natural range might be sufficiently strong to affect the willingness to cooperate.

Addressing this question, we set out to investigate whether cooperative preferences, as indexed by SVO, fluctuate across the natural female menstrual cycle. To this end, we conducted two independent online studies, as this allowed us to collect self-reported menstrual cycle information in addition to SVO across the entire menstrual cycle rather than during (more or less arbitrarily defined) time windows only. This procedure enabled us to control for potential belief effects as participants' cycle phases did not have to be determined prior to psychological testing. This is particularly important because previous studies have revealed that people do indeed show strong belief effects about hormonal influences on social behavior (Eisenegger, Naef, Snozzi, Heinrichs & Fehr, 2010). Furthermore, social measures may be specifically sensitive to experimenter effects and influences related to repeated testing, so an approach in which every participant is tested only once and without interaction with any experimenter seemed most appropriate for the present purposes. Even though cycle information obtained via self-report is a less accurate measure of cycle phase and hormonal state compared to blood/saliva samples, we sought to compensate for the higher error variation by substantially larger sample sizes, as can be relatively easily achieved in online studies (for a similar reasoning, see Scott & Pound, 2015).

To our knowledge, no prior studies have examined hormonal variations of cooperative preferences across the menstrual cycle. However, several studies suggest that the ability to recognize other people's emotions, a component of cognitive empathy that has been shown to be associated with SVO (Declerck & Bogaert, 2008), is increased in the follicular phase compared to the luteal phase (e.g., Derntl et al., 2008; 2013; Guapo et al., 2009; but Pearson & Lewis, 2005). We therefore assumed that the changes in cooperative preferences across the menstrual cycle would most likely occur between these two phases and tentatively expected women in the follicular phase to be more prosocial than women in the luteal phase.

Furthermore, we aimed to explore whether SVO variations observed across the menstrual cycle would be predictable from typical cycle-dependent fluctuations in ovarian steroids (i.e., estrogen and progesterone), which are known to be important modulators of social behavior at least in non-human mammals (e.g., Beery, Loo & Zucker, 2008; Huck, Carter & Banks, 1979). Following previous studies (Lukaszewski & Roney, 2009; Roney & Simmons, 2008), day-specific hormone levels of women in our samples were estimated based on published values obtained from an unrelated sample of naturally cycling women (Stricker et al., 2006). We ran one study in Germany (Study 1), and a replication study in the US (Study 2). Menstrual cycle information was assessed prior to cooperative preferences in Study 1, but after cooperative preferences in Study 2, to control for potential belief effects.

# 2 Methods

## 2.1 Participants

### 2.1.1 Study 1

For Study 1, our goal was to collect $N$=89 valid observations available for the regression analysis predicting SVO from estimated hormone levels, which corresponds to the sample size necessary to find a medium sized effect (*Cohen's* $f^2$ = .15) with a test power of 95% as determined by G*Power 3.1 (Faul, Erdfelder, Buchner & Lang, 2009), while at the same time providing a sample size of more than 20 observations per cell for the comparison of SVO angles between the early follicular and the midluteal phase (Simmons, Nelson & Simonsohn, 2011). Data collection was stopped the day after this aim was reached. In total, $N$ = 497 women, who were recruited via German internet forums and social media platforms, completed our online survey in Study 1. Participants were asked for their mean menstrual cycle duration in the last six months and whether they (1) had used the contraceptive pill or any other form of hormonal contraception in the last six months, (2) were taking hormonal supplements other than hormonal contraceptives, (3) were pregnant or breastfeeding, or (4) were going/had gone through menopause. Participants qualified for the main analysis if they negated questions 1 to 4 and reported a mean menstrual cycle duration between 24 and 32 days across the last six months, following previous studies (Andreano, Arjomandi & Cahill, 2008), resulting in a sample of $N$ = 103 women for analysis of menstrual cycle data (age: 17–43 years, $M$ = 25.92, $SD$ = 5.78; cycle duration: $M$ = 28.31, $SD$ = 1.84). Results obtained with more liberal exclusion criteria are depicted in Table S1 and Table S2 of the supplementary results. They agree with those of the current sample.

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#### 2.1.2 Study 2

For Study 2, we envisaged about 2.5 times as many participants compared to Study 1 to provide acceptable power for replication (Simonsohn, 2015). We stopped data collection by the end of the planned test period of 21 days (as preset on Amazon Mechanical Turk; *MTurk*). In total, a sample of $N = 330$ women living in the United States, who were recruited via MTurk, completed our online survey. MTurk is an online labor marketplace allowing researchers to recruit participants in exchange for a small financial compensation. To promote data quality, women were allowed to participate only if they had a total approval rate of 90% or higher in previous MTurk assignments. Participation in our study was rewarded with a small financial recompense of $0.40. At the end of the survey (i.e., after the assessment of cooperative preferences), participants were asked for their mean cycle duration, by how many days the onset of their menstruation had varied counted from the mean cycle duration in the last six months (i.e., the regularity of their menstrual cycle), and whether they (1) had used the contraceptive pill or any other form of hormonal contraception in the last three months, (2) had taken hormonal supplements other than hormonal contraceptives in the last six months, (3) were pregnant or had given birth in the last twelve months, or (4) were going/had gone through menopause. Participants were included in the main analysis if they negated questions 1 to 4 and reported a mean menstrual cycle duration between 24 and 32 days across the last six months, following previous studies (Andreano et al., 2008), resulting in $N = 209$ women available for analysis of menstrual cycle data (age: 18–45 years, $M = 30.53$, $SD = 7.23$; cycle duration: $M = 28.37$, $SD = 1.88$). For more detailed information regarding the exclusion criteria and results obtained with more liberal exclusion criteria, see Table S1 and Table S2 in the supplementary results.

## 2.2 Measures

Participants responded to the menstrual cycle survey prior to assessment of SVO in Study 1, whereas this order was reversed in Study 2 to control for potential belief effects. It was not mentioned to the participants of Study 2 that they would be asked to provide information about their menstrual cycles later in the survey until after they had filled out the SVO questionnaire, although it was mentioned that "factors which can influence your hormonal state" will be assessed. This is a very vague description that nonetheless fulfilled ethical requirements of fully informed consent.

#### 2.2.1 Menstrual cycle survey

In both Study 1 and Study 2, participants were asked to answer questions that assessed inclusion criteria (see section 2.1). In addition, to determine cycle day and cycle phase, participants reported the start date of their last menses with the help of a calendar we provided. Based on this information, we calculated each woman's cycle day (cycle day 1 = first day of menses) and assigned $n = 25$ (Study 1) [$n = 43$ (Study 2)] participants to the early follicular (cycle days 1 to 7: low levels of estradiol and progesterone) and $n = 22$ (Study 1) [ $n = 47$ (Study 2)] to the midluteal group (cycle days 18 to 24: high levels of estradiol and progesterone), following previous studies (e.g., Andreano et al., 2008). No group differences in age or mean cycle length were found in either Study 1 or Study 2 (all $p$s $> .3$). Results obtained for alternative methods to determine each woman's position in the menstrual cycle and for several slightly different time windows characterizing the early follicular and the midluteal phase found in the literature are provided in Tables S1 and S2 of the supplementary results; all items of the menstrual cycle surveys of the two studies are listed in the supplementary methods.

#### 2.2.2 Assessment of SVO

Furthermore, participants filled out the six primary items of the *SVO Slider Measure* (Murphy et al., 2011; available at http://journal.sjdm.org/11/m25/m25.html), a continuous measure of SVO that shows high reliability as well as good convergent and excellent predictive validity (Kinnunen & Windmann, 2013; Murphy et al., 2011), in its German (Study 1) [English (Study 2)] version. For each item, the task was to indicate the preferred distribution of fictitious monetary amounts between oneself and an anonymous other person with joint outcomes ranging between 100 and 170 Euros (Study 1) [US Dollars (Study 2)]. Based on these choices, the inverse tangent of the ratio between the mean allocation for themselves minus 50 and the mean allocation for the other minus 50 was computed to obtain each participant's individual SVO index following Murphy et al.'s (2011) instructions. This resulted in angles between –16.26° and 61.39° (*SVO angle*), with larger angles reflecting more prosocial and smaller angles more individualistic preferences.

In addition to the menstrual cycle survey and SVO, some other measures were assessed in the two studies; these are unrelated to the present research question but are listed in the supplementary methods.

## 2.3 Hormone estimation

To predict SVO variations of women in our sample from typical fluctuations of estrogen and progesterone, respectively, we assigned estimated concentrations of these two hormones to each cycle day. Specifically, we used previously published data on median estradiol and progesterone values across the menstrual cycle, obtained in daily serum samples (Stricker et al., 2006) to estimate estrogen and progesterone levels in our samples, following prior studies

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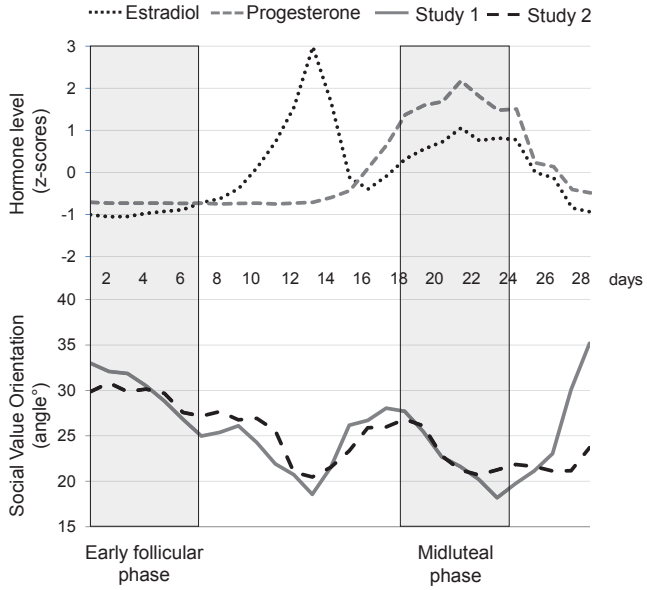
Figure 1: Top: Z-scores of median estradiol and progesterone concentrations per cycle day (as reported by Stricker et al., 2006), with the LH surge estimated to occur on day 14. Bottom: Social Value Orientation angles (larger values indicate more prosocial preferences) for each cycle day for Study 1 and Study 2. Social Value Orientation scores are five-day centered moving averages weighed by the number of participants per cycle day. Gray shaded areas represent the early follicular (cycle days 1 to 7) and midluteal phase (cycle days 18 to 24).




(Lukaszewski & Roney, 2009; Roney & Simmons, 2008). Stricker et al. (2006) provided day-specific hormone levels relative to the day of the surge of the luteinizing hormone (*LH surge*). Women in our final samples reported a mean cycle length of $M$ = 28.31 (Study 1) / $M$ = 28.37 (Study 2), with more than 80% of women in both Study 1 and Study 2 indicating a mean cycle length between 26 and 30 days. Given that the LH surge occurs on average 14 days prior to the last day of the menstrual cycle (e.g., Bakos, Lundkvist, Wide & Bergh, 1994; Lenton, Landgren & Sexton, 1984), corresponding to day 14 in a 28-days cycle, we used this as our reference point and assigned estimated hormone levels accordingly. Women who reported a cycle day above 28 had to be excluded from these analyses because estimated hormone values were not available for these cycle days.

# 3 Results

First, we compared SVO angles of women in the early follicular with those in the midluteal phase (gray shaded areas in Figure 1) with a two-sample t test. As hypothesized, SVO angles were significantly larger (i.e., more prosocial) in the early follicular phase in both Study 1 and Study 2 (Study 1: $M_{early\ follicular}$ = 30.09°, $M_{midluteal}$ = 21.35°; $t(45)$ = 2.18, *95% CI*$_{diff}$ [0.67°, 16.82°], $p$ = .03; *Cohen's d* = .64; Study 2: $M_{early\ follicular}$ = 29.69°, $M_{midluteal}$ = 23.05°, $t(88)$ = 2.25, *95% CI*$_{diff}$ [0.84°; 12.43°], $p$ = .03; *Cohen's d* = .48). The significance of these results was not altered when age, mean cycle length, or regularity of the menstrual cycle (Study 2) were entered into the analyses as covariates, or when we used a bootstrap approach with 1,000 repetitions as a more conservative test for the comparison of means.

Second, we used previously published data on estradiol and progesterone serum levels collected daily across the menstrual cycle in an unrelated sample of women (Stricker et al., 2006) to statistically predict SVO angles in a regression analysis (Study 1: $N$ = 90; Study 2: $N$ = 182). Regression analysis revealed that estradiol (Study 1: $p$ = .03; Study 2: $p$ = .01), but not progesterone (Study 1: $p$ = .73; Study 2: $p$ > .99) was a significant predictor of SVO in both studies, with a negative correlation as higher estradiol concentrations were associated with smaller (i.e., more individualistic) SVO angles (Study 1: $ß_{stand}$ = –.25; *95% CI* [–.48; –.03]; Study 2: $ß_{stand}$ = –.22; *95% CI* [–.38, –.05]; see Figure 1). The two-way interaction between estimated estradiol and progesterone levels did not approach significance when entered into the regression analysis for either study (Study 1: $p$ = .39; Study 2: $p$ = .76). As an additional check, we also used testosterone values reported by Garver-Apgar and colleagues (2008) as predictors of SVO, but found no significant correlation in either of the two studies (Study 1: $p$ = .98; Study 2: $p$ = .37). Estimated estradiol remained a significant predictor of SVO in both studies when age, mean cycle length, or regularity of the menstrual cycle (Study 2) were controlled for statistically, or when significance was assessed using a bootstrap approach with 1,000 repetitions as a more conservative test.

# 4 Discussion

In two independent online studies we found that cooperative preferences, as reflected in SVO, vary substantially across the natural menstrual cycle. First, women in the early follicular phase were more prosocial than women in the midluteal phase. Second, across-cycle estimates of estradiol, but not progesterone or testosterone, predicted shifts in cooperative preferences across the cycle, with a negative correlation. (Note, however, that the counting method we used provides more statistical power to earlier peaking hormones such as estradiol due to increasing error variance with number of cycle day.) These results suggest that a woman who appears prosocially oriented during the early follicular phase has a substantial chance to be classified as individualistic when tested two or three weeks later, presumably due to the effects of estradiol: Whereas 84% (Study 1) [77% (Study 2)]

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of the women in the early follicular phase were categorized as prosocial (as opposed to individualistic), this was true for only 55% (Study 1) [64% (Study 2)] of the women in the midluteal phase. This difference of at least 13% (in Study 2) is within the range that Murphy et al. (2011) have observed for a 1-week-period in a mixed sex sample. Such changes have previously been attributed to limited retest reliability of SVO, but our results suggest that at least some of the variation is due to the influence of natural endocrine fluctuation. This finding is in line with recent evidence suggesting that SVO might—in addition to its trait-like properties—contain a more dynamic component (e.g., Ackermann, Fleiß & Murphy, 2014; Hysek et al., 2014).

The negative covariation between SVO and estimated estradiol levels observed here is consistent with findings from a recent study where estrogen and progesterone metabolites in women's morning urine observed for 42 days contributed negatively to how well these women reported to get along with other people two days later (Schwartz, Romans, Meiyappan, De Souza & Einstein, 2012). Against the background of our findings, one may speculate that estradiol-driven reduction in prosociality might decrease the number of cooperative social interactions, and perhaps give rise to more interpersonal conflicts, thereby reducing the quality of social relationships on the following days.

From a more general perspective, influences of estradiol and other gonadal steroids on social behavior might at least partially account for some of the gender differences that have previously been reported for cooperative behavior (Van Vugt, De Cremer & Janssen, 2007), desire for revenge (Singer et al., 2006), and empathy (e.g., Knickmeyer, Baron-Cohen, Raggatt, Taylor & Hackett, 2006). The same holds for sex differences in the prevalence of psychiatric conditions with a strong socio-emotional component such as autism and anxiety disorders (e.g., Baron-Cohen, Knickmeyer & Belmonte, 2005; Cover, Maeng, Lebrón-Milad & Milad, 2014). In this sense, our findings add to the growing body of literature characterizing estradiol and other gonadal steroids as regulators of cognitive and affective processes and the associated brain functions (reviewed in Toffoletto, Lanzenberger, Gingnell, Sundström-Poromaa & Comasco, 2014), above and beyond their role in sexual motivation and behavior (e.g., Wallen, 2001).

Obviously, our interpretations are based on a correlational design, so it remains unresolved whether the observed association between estimated estradiol levels and SVO, albeit significant and replicated, reflects a *causal* role of estradiol in shifting cooperative preferences as opposed to other (non)endocrine factor(s) (or perhaps a combination of these). Notably, this limitation generally applies to all menstrual cycle studies, whether or not hormone levels have directly been assessed. In fact, we would argue that unless measurements are done repeatedly with a high sampling rate across the entire cycle rather than during two or three timepoints only, as typically done, laboratory studies using hormone assays may actually be *more* limited in that regard than our approach.

Notwithstanding the question of which specific neurophysiological mechanism(s) underlie the reported SVO fluctuations across the menstrual cycle, our findings do strongly suggest that they are *systematic* and not just coincidental. This is because we observed highly similar effects across two independent samples of women for both the categorical (i.e., phase comparisons) and the continuous measure (i.e., correlations with estimated hormones). The replication in particular suggests an oscillatory cycle of approximately 28 days, anchored to the first day of the menstruation phase. At present, we cannot think of any other biological factor than the female menstrual cycle that meets this requirement. Furthermore, the obtained results were robust in that, as long as major hormonal disruptors such as hormonal contraception and pregnancy were absent, they remained intact independent of whether exclusion criteria were more or less restrictive and which particular cycle phase definitions were used (see supplementary results). This is particularly important in light of the ongoing debate about recent replication failures regarding menstrual cycle effects, in which the issue has been raised that some of the originally reported effects may reflect false positive results caused by high researcher degrees of freedom when it comes to the specific methods they decide to use to analyze their data (Gelman, 2015; Harris, Chabot & Mickes, 2014). In agreement with others (Gelman, 2015; Scott & Pound, 2015), we call for presentation of all data under various analyses in future studies, including a depiction of the time-course of the fluctuation across the entire cycle, to provide maximal transparency.

Nonetheless, it should be noted that cycle lengths and circulating hormone levels are subject to considerable variability between and within individuals, in addition to the inevitable and well-known inaccuracies in self-reported menstrual cycle information (e.g., Becker et al., 2005). Evidently, one needs larger sample-sizes to account for the reduced reliability of such self-report data compared to blood or saliva samples. Notably, however, unsystematic measurement error should make it more difficult (rather than easier) to detect differences between cycle phases and hormone-outcome associations (for a similar argument, see Lukaszewski & Roney, 2009; Scott & Pound, 2015), so that results like those reported here cannot be explained in terms of measurement error, especially given the replication in Study 2.

In conclusion, our studies show that SVO varies across the menstrual cycle, potentially as a function of estradiol. The reported results extend previous evidence in that they suggest hormone fluctuations within the natural range to be sufficient to substantially change a woman's inclination to cooperate and highlight the importance of investigating psychological effects of ovarian hormones, which have been

largely neglected in administration studies, albeit their synthetic derivates are taken daily by millions of women in the form of contraceptive pills.

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