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Cognitive Neuroendocrinology: Risk Preference Changes Across the Menstrual Cycle

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Abstract

There is growing evidence that hormones play an important role in a number of cognitive processes. This challenges the concept of the brain as a computer in favor of it being thought of as a gland. However studies of hormones and cognition have often lacked clear hypotheses. The current study based its hypothesis on an evolutionary analysis. Previous studies suggest that women selectively reduce activities increasing risk of sexual assault when ovulating. Oral contraceptives blocked this effect, suggesting a hormonal mechanism. This study tested if there was a general decrease in risky choices during ovulation. 176 women were classified as menstrual, postmenstrual, ovulatory or premenstrual, and chose between a guaranteed (\$85) or risky outcome (85% chance of \$100). Phase affected rate of risky choice only for women not taking contraceptives. The effect was entirely due to risky choices dropping to 0% for ovulating women not taking contraceptives. This adds to evidence that understanding neurochemistry is important for understanding decision making, and adds to the plausibility of a field of cognitive neuroendocrinology.

Keywords: Decision making; risk; hormones; menstrual cycle, evolutionary psychology.

Introduction

The dominant metaphor for the brain has been the computer thus the biological basis of cognition has been seen in terms of circuits and connections (Thagard, 2002). However recent advances in knowledge about how the brain works has suggested that more than connections are involved as the biochemistry of the brain is crucial to its operation. The most obvious illustration of this is the effectiveness of psychoactive drugs for treating mental illness, but unintended psychological effects of drugs do so as well. For example, a recent study reported cases of patients with Parkinson Disease who become compulsive gamblers as a result of taking medication for their condition (Dodd, Klos, Bower, Geda, Josephs, & Ahlskog, 2005). Perhaps seeing the brain as a computer is insufficient, instead the brain may be thought of as a gland (Bergland, 1985).

Neuroscience has started to have an impact on the understanding of complex cognition, such as decision making. A good example of this is in the work of Damasio (1994), who found that brain lesions which impaired processing of emotion also impaired decision making. A recent study by Kosfeld, Heinrichs, Zak, Fischbacher, and Fehr (2005) reported evidence of hormones influencing decision making. They found that giving players of a trust

game a nasal spray of the hormone oxytocin increased the extent to which participants decided to trust their partners.

Much of the recent work in the growing field of cognitive neuroscience has focused on what areas of the brain appear to be involved in different aspects of cognition. This is also true of the emerging field of neuroeconomics which is largely interested in the relationship between the brain and types of decision making. However by largely ignoring the role of hormones these fields may be leaving out half the story. This paper aims to test a hypothesis implying a hormonal effect on decision making, and as such to illustrate why taking into account hormones could be critical. There is no specific name for this field, but it could be appropriately described as *cognitive neuroendocrinology*.

Hormones and Cognition

It is not the case that the role of hormones in cognition has been totally ignored. Within the literature on stress the role of hormones on cognitive performance has often been considered (e.g., Taylor, Klein, Lewis, Gruenewald, Gurung, & Updegraff, 2000). Studying the cognitive impact of hormone therapy for postmenopausal women (Drake, et al., 2000) or those being treated for breast cancer (Shilling, Jenkins, Fallowfield, & Howell, 2003) has become important. There is starting to be clear evidence of affects of hormones on vision (Gupta, Johar, Nagpal, & Vasavada, 2005), working memory (Rosenberg & Park, 2002), attention (Beaudoin & Marocco, 2005), and navigation (Driscoll, Hamilton, Yeo, Brooks, & Sutherland, 2005). Some of these findings may be a consequence of hormonal effects on hemispherical asymmetry (Hausmann, 2005). However the results of this research are often unclear and sometimes contradictory, so the conclusion from Richardson's (1992) survey of the then existing literature, that it is hard to draw clear principles from this work, appears to still hold.

Much of the work on hormones and cognition has studied the effects of the menstrual cycle on women. This has many methodological advantages as the menstrual cycle produces strong and predictable hormonal changes without any need to intervene or manipulate a person's hormones. Despite the methodological advantages of studying variations across the menstrual cycle the fact that different studies have focused on different points in the cycle has added to the difficulty of drawing clear conclusions across the studies. The literature has often lacked clear hypotheses because there was little basis on which to say what the critical points in the cycle should be for cognition. A possible way to generate hypotheses is by taking an evolutionary approach.

An Evolutionary Approach: Ovulation and Risk of Sexual Assault

Evolutionary psychology has been criticized as telling post-hoc stories about existing data, but its greatest value may be when it can be used to generate novel predictions (Cosmides & Toby, 1999). From an evolutionary viewpoint, the critical point of the menstrual cycle for decision making should be ovulation, because that is when pregnancy is most likely to occur and thus critical choices are made that affect which male genes will contribute to future generations. One implication of this is that there may have been evolutionary pressure for women to develop mechanisms that reduced the risk of rape during ovulation.

Following this logic, two studies have tested the prediction that women's menstrual cycle may affect their engagement in behavior that may increase their risk of sexual assault. Chavanne and Gallup (1998) and Bröder and Hohmann (2003) tested this hypothesis by asking women about their behavior over the last 24 hours and differentiating between behaviors that may increase a woman's risk of attack (e.g., walking in a dimly lit area) and those that were considered relatively safe (e.g., watching TV). Both studies found evidence consistent with the claim that there was a relative decrease in risky behaviors by ovulating women, but only if they were not taking a hormonal contraceptive. Thus these studies concluded that women change their behavior over the menstrual cycle by reducing the frequency of engaging in behavior that might increase the risk of losing control of being able to select the father of their children, and they do so at the time when the chance of pregnancy is greatest. Note that the critical point is loss of control of the decision over which genes may be passed onto the next generation, so these results do not contradict evidence that there is an overall increase in sexual intercourse for women who are ovulating (Wilcox, Weinberg, & Baird, 1995). The critical issue is choice and loss of that choice through sexual assault. Consistent with this is the finding that increases in sexual interest at time of ovulation are selective rather than uniform (Gangestad, Thornhill, & Garver-Apgar, 2005).

That hormonal contraceptives can block the effect found by Chavanne and Gallup (1998) and Bröder and Hohmann (2003) suggests that the mechanism is hormonal. However, if such a hormonal mechanism has evolved, then it may well be more general than specific behaviors such as walking in dimly lit areas. Instead it may lead to a more general avoidance of risk. Therefore this paper will test the hypothesis that ovulation may lead to a general decrease in preference for risk. However, if what the earlier studies discovered was a mechanism specific to minimizing risk of sexual assault at ovulation, then there should be no impact of the menstrual cycle on a test of general risk preference.

The Current Study: Generalizing the effect

The hypothesis that women who were ovulating would have a lower general preference for risk was tested by presenting women with a standard choice between a guaranteed

outcome (\$85) or a risky outcome (a 85% chance of \$100) and asking them which they preferred. It was predicted that for women taking hormonal contraceptives (most of which should block ovulation) there will be no impact on their preference as a function of menstrual phase, however women who were not taking such contraceptives and could be classified as ovulating should have a lower rate of selecting the risky choice relative to women classified as being in other phases of their menstrual cycles.

Method

Participants

A total of 444 undergraduate students at Michigan State University participated for partial course credit. There were no gender restrictions on participation so 133 of these participants were men. Overall, there was no difference in the percentage of men (30.0%) choosing the risky option (\$85 rather than the 85% chance at \$100) and the percentage of women (30.1%) doing so, $X^2(1) = .010, p = .92$. Of the women, 271 indicated the first day of last menstruation and of these 176 indicated that they had a regular menstrual cycle. All of these women answered the question regarding whether they were taking a hormonal contraceptive (overall, only 5 of 311 women did not answer this question). These remaining 176 women had an average age of 19.9 years, and were the sample analyzed in this paper.

Procedure

Participants were recruited to do a set of experimental tasks. As part of this they were presented with the following task:

You just won a prize on a game show. The host gives you two choices. You can either take a sure prize of \$85 or you can spin a wheel for an 85% chance to win \$100 (but you'd have a 15% chance of winning nothing). Which choice would you prefer?

Choose One (circle your choice):

- A. The sure prize of \$85
- B. The 85% chance of winning \$100

After completing some more tasks the female participants were presented with the following questions:

What was the date of the first day of your last menstruation? _____

If you cannot remember the exact date please make the best estimate in terms of days: _____

Are your menstrual cycles irregular, shorter than 23 days, or longer than 33 days? YES NO

Are you currently using a hormonal contraceptive? (e.g., pill, patch, injection, ring) YES NO

Participants read that we are investigating a possible relationship between hormones and the decisions people make and they were told that “We cannot connect you to your survey. However, you are completely free to not answer any of these questions if you do not wish to.” Participants received no payment, only course credit.

Results

Classification

After excluding all men, and women who either did not answer all the questions or who indicated an irregular menstrual cycle, the remaining 176 women were classified as in the *contraceptive* “yes” or “no” groups. They were also classified into one of four menstrual cycle phase groups on the basis of how many days into their menstrual phase they were calculated to be. A participant indicating that today was the first day of her last menstruation would be assigned as being in “Day 1” and for all others their day was calculated by counting back to what they indicated was their first day. Women calculated to be in days 1 to 5 were classified as in the *menstrual phase*, if in days 6 to 12 as in the *postmenstrual phase*, if in days 13 to 17 as in the *ovulatory phase*, and if in days 18 to 28 as in the *premenstrual phase*. This method of classifications was the same as used by Chavanne and Gallup (1998). It is acknowledged to not be

completely reliable but it is considered reasonably accurate and it lacks any systematic bias.

The classification scheme resulted in 34 women being classified as in the menstrual phase (19 on hormonal contraceptives, 15 not), 51 as postmenstrual (28 on hormonal contraceptives, 23 not), 38 as ovulatory (18 on hormonal contraceptives, 20 not), and 53 as premenstrual (28 on hormonal contraceptives, 25 not).

Analysis

Figure 1 shows the proportion of participants who choose the risky option (85% chance at \$100) over the safe option (sure \$85) by whether or not they took hormonal contraceptives and which phase of their menstrual cycle they were classified as in. For women taking contraceptives there was no effect of which phase they were classified as in, $X^2(3) = .73, p = .86$, but there was for women not taking contraceptives, $X^2(3) = 11.0, p = .012$. The effect for woman not taking contraceptives was entirely due to the rate of choosing the risky option dropping to 0% for those in their ovulatory phase. This was statistically significantly different from the rate for women in their menstrual ($X^2[1] = 7.8, p = .009$), postmenstrual ($X^2[1] = 11.3, p = .001$), and premenstrual phases ($X^2[1] = 6.6, p = .010$). Although directly comparing the “yes” and “no” contraception groups

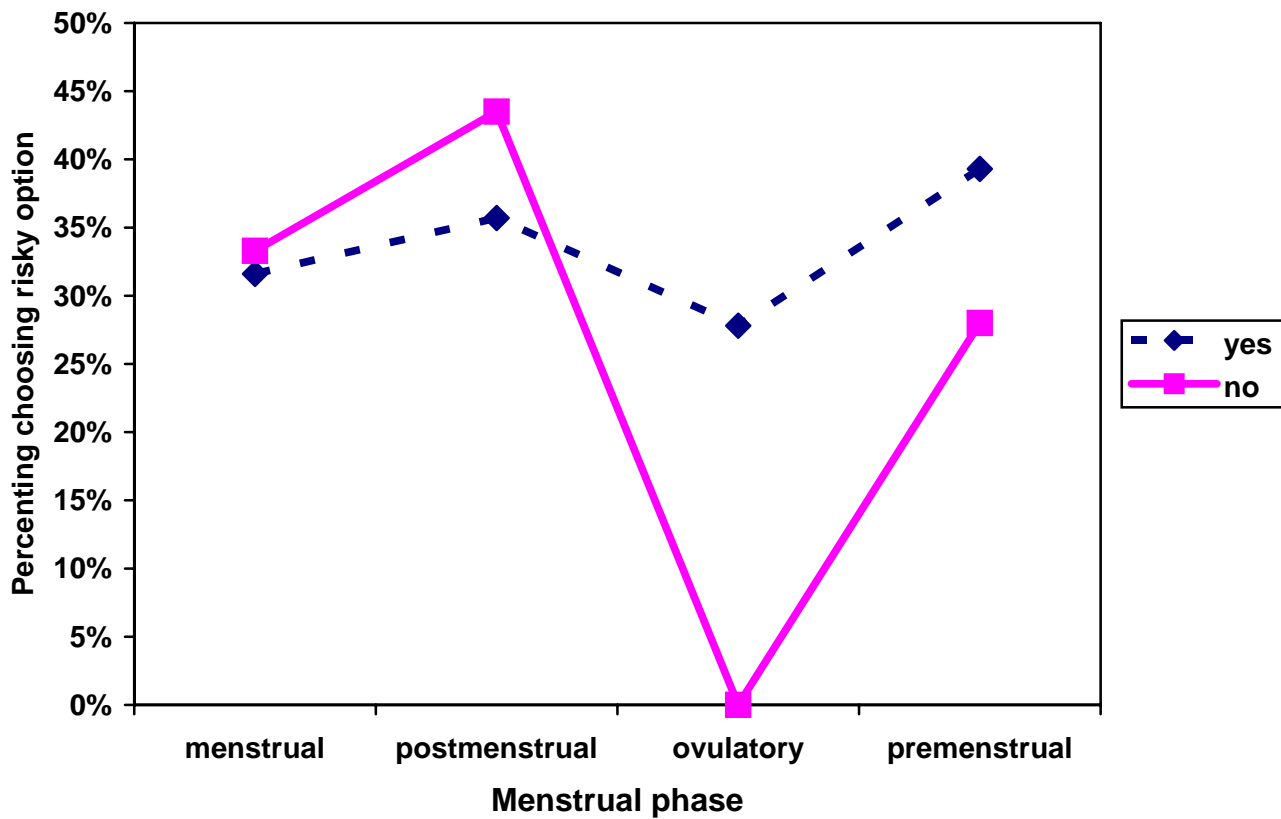


Figure 1: Percentage of women in each menstrual phase choosing the risky option depending on whether they were (“yes” line) or were not (“no” line) taking hormonal contraceptives.

has to be done with caution given that these are self-selecting groups, it is interesting that there is also a significant difference in the rates of preferring the risky choice between the contraceptive groups for women classified as being in the ovulatory phase ($X^2[1] = 6.4, p = .011$). Therefore the hypothesis was supported, women were less likely to make a risky choice at the likely time of maximum likelihood of pregnancy, but this effect was absent if they were taking hormonal contraceptives.

Discussion

The study supported the speculation that ovulation may decrease women's preference for risk. Furthermore, the finding that this menstrual phase effect was blocked by hormonal contraceptives argues that hormones play a role in people's preferences for risky or safe choices.

Note that it is difficult to argue that these results could be due to some form of learning or awareness of ovulation. Most women do not think they have awareness of when they are ovulating and many of those who do claim some awareness can be shown to be inaccurate in estimating when they are ovulating (Sievert & Dubois, 2005). Furthermore, hunter-gather societies are not aware of the link between ovulation and pregnancy (Marlowe, 2004) so this effect is unlikely to be due to some form of cultural learning. Thus avoiding risk at time of ovulation is unlikely to be some type of learned behavior as the stimulus is not perceived, and was not seen as significant until relatively recently.

Although this study only examined the effects of hormones on women, Kosfeld et al. (2005) focused on men, therefore there is no reason to think that hormonal influences on decision making are restricted to women. Whether the reduction in riskiness during ovulation is "better" or "worse" decision making overall is hard to say. Ovulation is the most critical time for determining what genes get passed onto the next generation; so arguable this should be the time that women are at their peak cognitively. Rosenberg and Park (2002) presented evidence that women's memory capacity is improved at time of ovulation. Of course the cognitive effects of hormones may well vary with gender. Rosenblitt, Soler, Johnson, & Quadagno (2001) found a relationship between measured cortisol levels and sensation seeking for men but not for women (interestingly, testosterone showed no relationship for either gender).

Which Hormones?

This study does not provide evidence regarding which particular hormones may explain the menstrual phase effect beyond suggesting that the candidates are hormones that are elevated at time of ovulation.

One such hormone is oxytocin which has been found to be elevated at time of ovulation but only in women not taking oral contraceptives (Salonia, Nappi, Pontillo, Daverio, Smeraldi, Briganti, Fabbri, Zanni, Rigatti, &

Montorsi, 2005). As described earlier, Kosfeld, et al. (2005) reported evidence of oxytocin influencing decision making in a trust game and there is evidence of intriguing behavioral effects of oxytocin (see Gimpl & Fahrenholz, 2001, for a review). However, Kosfeld, et al. argued that their results were not due to a change in risk preference. They ran another experiment with a game identical in terms of payoff and risks to the trust game but that did not involve a human partner. Administering oxytocin under these conditions had no impact on how the game was played.

Peaks in levels of luteinizing hormone are what trigger ovulation, so it is a candidate. Yet there are currently no reported behavioral effects of luteinizing hormone.

Estrogen is the critical component of many forms of hormonal contraceptive and it is also elevated during ovulation (Alliende, 2002), so it is an obvious candidate for explaining the effects of ovulation on risk preference. However any such explanation would need to reconcile why there was no evidence of an effect of taking estrogen in the form of contraceptive pills on risk preferences. Such a reconciliation may be possible (perhaps it is fluctuations that are critical), but would require evidence.

Thus the exact nature of the hormonal mechanism producing fluctuations in riskiness over the menstrual cycle is unclear at the moment. However this study has provided a clue as to what to look at.

A Mechanism: The Nucleus Accumbens?

As well as lacking evidence regarding which hormones are critical for explaining this effect, it is difficult to know what brain structures may be responsible for it. However there is fragmentary evidence that could be combined to produce a speculation that the nucleus accumbens is a critical structure.

Two relevant findings regarding the nucleus accumbens have been reported that may connect it to the menstrual phase effect. First, an fMRI study has found evidence of greater activation in the nucleus accumbens when a person is about to make a risky choice as opposed to a nonrisky choice (Matthews, Simmons, Lane, & Paulus, 2004). Second, there is evidence that estrogen affects the nucleus accumbens of the rat (Becker, 1999). Thus this is a brain structure which is both implicated in risk preference and is affected by a hormone that is elevated at time of ovulation; however there is no direct evidence that this is more than coincidence.

Although the suggestion that the nucleus accumbens may play a role in the effects this paper reports is very speculative, this is not the first time it has been proposed that the nucleus accumbens plays a role in decision making. Wagar and Thagard (2004) propose a model in which the nucleus accumbens plays a critical gating role for how emotional information may influence decision making. Damasio (1994) proposed that critical for decision making are somatic markers from the ventromedial prefrontal cortex

(VMPFC) and amygdala. Wagar and Thagard propose a computational model assuming a network of connections between these areas, the nucleus accumbens and the ventral tegmental area in which the nucleus accumbens gates the access of the somatic markers to the areas of the brain responsible for higher-order cognition. They give such a role to the nucleus accumbens because of evidence that the nucleus accumbens is responsible for mediating basic locomotive and appetitive behaviors driven by affective states (Mogenson, Jones, & Yim, 1980), that it receives afferent connections from the other brain structures that make up their model (O'Donnell & Grace, 1995), and that the nucleus accumbens appears to have a gating effect on facilitation.

Implications: A field of cognitive neuroendocrinology?

These results require replication, in particular one utilizing a within-subject design and physical confirmation of ovulation. There is also a need to explore exactly how general the drop in risk preference is at ovulation. However statistically the results are strong, the pattern fits exactly to that predicted, and they are consistent with the apparent drop in specific risky behaviors at ovulation found by Chavanne and Gallup (1998) and Bröder and Hohmann (2003). Thus there is reason to think the results of the single study reported here will stand up, and if they do then they have important implications.

Beyond the implications for understanding decision making in general, finding that hormones may have strong influences on decision making may have important implication for medical treatment. Many diseases and their treatments have strong effects on hormones of patients who may be asked to make critical decision weighing up the risk of future treatments. If Parkinson disease medication can lead to compulsive gambling (Dodd, et al., 2005) then it could severely effect the way such patients choose between potential treatment options. The results reported here suggest that other drugs may also have such implications.

Overall, the findings that hormones influence even complex cognitive processes, such as decision making, add to the growing body of evidence that understanding the neurochemistry of the brain will be critical to understanding its computational properties. As Thagard (2002) points out, this has been a largely neglected aspect of cognitive science and it shifts the view of the brain as a computer more towards the brain as a gland. This paper suggests ways around the barriers that have existed to stunt the development of a "cognitive neuroendocrinology." Both evolutionary theory and use of neuroimaging have grown recently in their influence on psychology. Using these tools it may be possible to reduce the difficulty of generating hypotheses about what hormones to examine and when. In this paper an evolutionary argument was used to justify its hypotheses and recent findings from imaging studies were used to speculate about a possible mechanism for the effects found. Thus a field of cognitive neuroendocrinology would be

complementary to more traditional cognitive neuroscience that has tended to focus on what areas of the brain are involved in different aspect of cognition. Knowledge of what areas of the brain are involved in a cognitive process together with knowledge of what hormones affect those areas could suggest hypotheses about hormones. Conversely, findings regarding what hormones may be important for a cognitive process could suggest hypotheses for what structures to examine, given that we know which structures are particularly affected by different hormones.

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