Effect of Copulins on Rating of Female Attractiveness, Mate-Guarding, and Self-Perceived Sexual Desirability

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Abstract

Olfaction and chemical signaling play an important role in the mating behaviors of many taxa, yet there is minimal empirical research on human putative pheromones. A mixture of five volatile fatty acids secreted vaginally, identified and named “copulins,” significantly increase in concentration during the follicular phase and decrease in concentration during the luteal phase in nonpill using women. Men exposed to copulins exhibit an increase in testosterone, are inhibited in discriminating the attractiveness of women’s faces, and behave less cooperatively. According to Anisogamy, Sexual Selection and Parental Investment Theory, mammalian males, having low cost and high benefit from any copulatory interaction, may adaptively utilize any useful cues to identifying ovulating females and adjust their behavior accordingly in order to maximize their potential reproductive success. In the current study, we attempted a replication of Jütte and Grammer’s finding indicating copulins inhibit the ability of men to discriminate attractiveness of women’s faces, and we examined the role of copulins in self-reported mate-guarding behaviors and self-perceived sexual desirability. We utilized a randomized placebo-controlled design and as predicted, results indicated men exposed to copulins were more likely to rate themselves as sexually desirable to women and, on average, the copulin group rated women’s faces as more attractive than controls. There were no significant findings with mate guarding.

Keywords

copulins, ovulation, follicular phase, luteal phase, mate guarding

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Introduction

Females in many mammalian species undergo a period of time referred to as estrus, when they are most likely to conceive and are more receptive to copulation attempts by males (Miller, Tybur, & Jordan, 2007). During estrus, several primate species exhibit visual cues to their physiological status, like sexual swelling (Grammer, Fink, & Neave, 2005). Humans do not exhibit overt visual cues during ovulation. Thus, human ovulation is often termed concealed, which may provide some advantages to women, for example, increasing the appeal of monogamous pair-bonding thereby increasing male parental investment, increasing chances of successful cuckoldry, and decreasing the risk of infanticide (Grammer et al., 2005; Roberts et al., 2004).

Sexual Conflict and Parental Investment Theory explains the diverging and often conflicting evolutionary interests of males and females (Chapman, Aranyist, Bangham, & Rowe, 2003). The disparity between male and female potentials for lifetime reproductive success is reflected in the mating strategies adopted by each sex (Trivers, 1972). Sperm are produced throughout a lifetime, eggs, on the other hand, are finite. Eggs are also the more energetically costly sex cell. Any copulation event for a human female could result in 9 months of investment in a single offspring, thus females benefit from being selective in their mate choice. Male investment, on the other hand, can end with ejaculation. Males must compete for access to the limiting resource, in this case females, which results in some males monopolizing multiple females and other males

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being left out the mating game entirely. Females have a low risk of being left out the mating game, as mating with any female is low cost and high benefit for a male. Because the best interest of males and females are in conflict, with regard to reproductive success, an evolutionary “arms race” manifested as certain behavioral tendencies, such as mate guarding, and physiological adaptations, like nonadvertised ovulation, may be underway (Trivers, 1972).

Mate guarding and sexual jealousy occurs when a partner perceives a threat to their mating relationship (Buss, 2002). Buss (2002) described seven typical mate-guarding tactics: vigilance, violence, concealment, monopolization of time, sexual inducement, physical signs of possession, and possessive ornamentation. Some examples of these tactics include obsessive calling and checking the whereabouts of one’s partner, dissuading a partner from attending a social gathering where the opposite sex will be present, and even the custom of wedding rings that signify the wearer is already in a committed relationship.

Haselton and Gangestad (2006) showed that nonpill using pair-bonded women self-reported more flirtatious behavior and an increase in their partner’s mate guarding around ovulation. Near and during ovulation women are more likely to seek extrapair copulations. Women may choose to engage in a long-term relationship with men who are willing to invest their time and resources in an offspring but seek “sexy genes” during ovulation in an attempt to improve the overall genetic quality of their offspring while also cuckolding parentally investing men (Trivers, 1972). In self-report surveys, ovulating women do show an increased preference for more attractive men and an increased desirability for men besides their current partner. This result is more extreme when the woman’s primary partner does not possess “sexy traits” (Haselton & Gildersleeve, 2011). Gangestad, Garver-Apgar, Cousins, and Thronhill (2014) found that nonpill using women report greater self-assertiveness and engage in more behaviors aimed at resisting their partners mate guarding during their fertile phase. The women’s partners also self-reported more assertive behaviors toward their partner, while she was at high conception risk.

Increased mate-guarding behavior during ovulation may be related to something more than a response to changes in female behavior (i.e., increased flirtation and desire for extrapair copulation; Haselton & Gangestad, 2006). A large portion of research on sexual behavior concerns visual cues and behavioral signaling. Substantially less research has been devoted to olfactory influences as humans have traditionally been classified as microsmatic (poor smellers; Carlson, 2013). Porter et al. (2007) suggest that the perceived differences in human and other species olfactory capabilities might be due to the anatomical adaptation of bipedality and not a direct reflection of olfactory ability. The current study argues men may be able to detect odor changes related to the physiological status of women, and this may explain subsequent behavioral and physiological changes in men.

In a number of animals, including some primates, chemicals have been shown to advertise female ovulation and affect male mating behavior (Miller & Maner, 2011). These chemicals are referred to as pheromones. Pheromones are defined as chemicals released from an organisms’ body into the environment that result in certain responses, both physiological and behavioral, in conspecifics. Some well-known physiological responses in mammals include the Lee-Boot effect, the Bruce effect, and the Whitten effect (Grammer et al., 2005).

Cummins et al. (2011) reported a striking example of intrasexual aggression induced via a pheromone produced by female squid. A protein, Loligo β-microsemino, synthesized by female squid causes male squid upon contact to rapidly change from a calm state to one of extreme aggression, resulting in the exhibition of fighting displays. In their natural environment, female squid produces this protein and inserts it into the outer portion of the egg capsule. Males are attracted to egg capsules visually and upon contact with Loligo β-microsemino, become aggressive. Male–male competition ensues and the female squid benefits from the acquisition of the victor’s sperm. Laboratory studies showed that the presence of Loligo β-microsemino without a female or egg capsules present was enough to trigger behavioral shift in males. Loligo β-microsemino is related, albeit distantly, to a protein represented in female mammalian reproductive secretions.

In some primate species, females produce vaginal secretions that may influence males behaviorally and hormonally. Michael and Keverne (1970) reported that estrogen stimulated some primates to produce vaginal secretions containing a chain of five volatile aliphatic acids: acetic, propanoic, methylpropanoic, butanoic, and methylbutanoic. This mixture of fatty acids, called copulins, could potentially be classified as a pheromone, since they are produced vaginally and trigger certain behavioral and physiological reactions in conspecifics (Grammer et al., 2005).

Copulins were first identified within the vaginal secretions of rhesus monkeys (Macaca mulatta; Michael & Zumpe, 1982). Copulins are registered by male rhesus monkeys through olfaction and affect mate choice. Michael and Zumpe (1982) placed four bilaterally ovariectomized females into a social group with one male. Testosterone was administered to two of the females causing them to be more receptive to approach and mounting attempts. One of the testosterone treated females was also treated with synthetic copulins, while the other was treated with ether. Female treatments were altered every trial to control for male mate-choice bias. The results indicated that copulins significantly increased mounting attempts and ejaculations. This suggests copulins act as a significant olfactory stimulus affecting male rhesus monkey mating behavior by allowing them to discriminate, which females in a social group are ovulating (Michael & Zumpe, 1982).

A similar study was conducted with stump-tailed macaques (Macaca arctoides). Female stump-tailed macaques lack sexual swellings, yet males have been shown to discriminatorily engage in copulatory behavior with females during the periovulatory phase. Vaginal secretions were collected throughout the five menstrual phases, and males were exposed to cotton
swabs soaked in these secretions or salt water. Upon returning to the home cage, males exposed to secretions from the ovulatory phase showed increased exploratory and coercive sexual behaviors (Cerda-Molina, Hernandez-Lopez, Rojas-Maya, Murcia-Mejia, & Mondragon-Ceballos, 2006).

Matsumoto-Oda et al. (2003) identified a chain of six volatile fatty acids: mucus, acetic acid, propionic acid, butyric acid, isobutyric acid, and valeric acid in the vaginal secretions of chimpanzees. Four captive female chimpanzees were observed throughout their cycles. One female exhibited significantly higher levels of acetic and propionic acids in her vaginal secretions. She was also the only female to be followed by a male and impregnated during the study. Levels of acetic and propionic acids were stable across all the female’s cycles. Only the concentration of isobutyric acid fluctuated throughout the menstrual cycle. This finding suggests that isobutyric acid may act as a signal or cue to reproductive status. The other acids, specifically acetic and propionic, may play a role in advertising overall genetic quality and fecundity.

Cross-species comparisons between humans and primates that exhibit sexual swelling or seasonal breeding patterns suggest that ovulatory cues have been lost in humans. However, women do display some cues related to their reproductive status such as behavioral shifts. Grammer, Renninger, and Fischer (2004) reported that ovulating nonpill using women at night clubs in Vienna danced more provocatively, showed more skin, and self-rated their outfit choices as sexier and bolder. They interpreted their results to imply women consciously display social signals with their clothing choices. Men report their perception of a woman as a partner is altered by her clothing choice. Women models showing more skin are reported as attractive for a sexual partner but less attractive as a long-term mate (Grammer, Renninger, & Fischer, 2004). Other research shows that near ovulation, women report an increased preference for men, other than their partner, that possess more symmetrical bodies and immunocompatible odors (Singh & Bronstad, 2001). Grammer, Fink, and Neave (2005) found that 13.8% of unprotected extrapair copulations happened during ovulation. According to parental investment and sexual selection, women should be seeking both good genes and good parental partners. Women may form pair bonds with more parentally investing partners and sneak extrapair copulations during ovulation with men exhibiting sexy genes. Sperm competition will improve the overall genetic quality of a woman’s offspring, as the “best” sperm will impregnate her egg (Grammer et al., 2004; Trivers, 1972). Similar research demonstrates that women not only exhibit behavioral shifts but also shift in physical appearance throughout their cycles.

Symmetry is selected for in many species as an indicator of overall genetic quality. For example, fluctuating asymmetry in plants is a product of sexual selection and involved in signaling to pollinators (Möller & Eriksson, 1994). Human mating strategies may correlate with symmetry, in that higher symmetry, men are likely to develop short-term mating strategies and asymmetrical men are likely to develop long-term mating strategies (Haselton & Gangestad, 2006). The sexy genes discussed in previous paragraphs is a reference to symmetry, among other factors (Grammer et al., 2004; Trivers, 1972). Women exhibit fluctuating asymmetry in relation to the menstrual cycle (Roberts et al., 2004). Soft tissues (ears, fingers, and breast) become more symmetrical during ovulation (Manning, Scutt, Whitehouse, Leinster, & Walton, 1996). Other subtle shifts in a woman’s physical features include lighter facial skin pigmentation, improved waist-to-hip ratio, and fluctuations in vocal pitch (Miller & Maner, 2011; Van den Bergh & Frost, 1986). Men judge photos of a woman not using hormonal contraceptives as more attractive during the follicular phase and less attractive during the luteal phase, suggesting that men may use fluctuating asymmetry as a cue to reproductive status (Roberts et al., 2004).

Miller, Tybur, and Jordan (2007) found that nonpill using lap dancers earned US$350 in tips while ovulating compared to US$260 in the luteal phase and US$185 during menstruation. One hypothesis based on behavioral differences suggests the discrepancy in earnings is due to more flirtation and provocative dancing during ovulation. Another hypothesis suggests men are unconsciously detecting olfactory cues to the physiological status of the dancer (Haselton & Gangestad, 2006; Haselton & Gildersleeve, 2011).

Michael, Bonsall, and Kutner (1975) examined vaginal secretions throughout the menstrual cycle of 50 young women via a tampon method. Their findings show that humans produce the same copulins as nonhuman primates and that copulins increase in concentration significantly during high fertility phases and decrease during low fertility phases. Before entering into a discussion on chemical communication via copulins in humans, it is worth mentioning that copulins could be a byproduct of shared phylogeny with nonhuman primates and of little importance in modern society. This will be brought up again in the discussion of future research (see the Section Discussion of Men’s Behavior in Response to Copulin Exposure). Michael et al. (1975) found that women using oral contraceptives were clearly distinguishable from normal cycling women because the overall content of fatty acids in their vaginal secretions was low and there was no alteration in concentrations throughout their menstrual cycle. Acetic acid was the most dominant acid found in the participants’ vaginal secretions, which is congruent with chimpanzee vaginal secretion findings (Matsumoto-Oda et al., 2003). In the chimpanzee study described earlier, researchers suggested that acetic and propionic acid signal overall female genetic quality because of their relatively stable concentrations across the menstrual cycle. Isobutyric acid, on the other hand, fluctuates throughout the menstrual cycle, and these fluctuations may be detected by males (Matsumoto-Oda et al., 2003). Acetic acid in human vaginal secretions is also relatively stable across the menstrual cycle and has a high threshold for olfaction. Thus, acetic acid, although the most dominate, contributes the least to vaginal odor. Waltman et al. (1973) reported isobutyric acid, which typically fluctuates the most in human vaginal secretions across the menstrual cycle, decreases in production by postmenopausal women. Postmenopausal women do not ovulate and...
subsequently do not need to secrete an acid that plays a role signaling reproductive status. Thus, changes in men’s behavior and perceptions surrounding an ovulating woman may not be solely due to changes in her behavior and fluctuating asymmetry but also related to fluctuations in concentrations of copulins, specifically iso-butyric acid, in her vaginal secretions.

Many studies show men are able to distinguish nonovulating women from ovulating women via scent alone. In one example of a classic smelly T-shirt study, nonpill using women in both the luteal and follicular phases wore t-shirts to bed for three days in a row. Afterward, men judged the scent of these T-shirts. Results indicated that men preferred the scent of women in the follicular phase. They rated those T-shirts as the most pleasant and sexy smelling (Singh & Bronstad, 2001).

Miller and Maner (2010) took hormonal measurements after exposing men to T-shirts worn by ovulating and nonovulating women. Men exposed to T-shirts worn by ovulating women exhibited a significant increase in testosterone. Testosterone has been implicated in, among other things, aggressive behaviors like competitiveness and dominance. These are traits that may be valued by women, especially during ovulation, and are related to intrasexual aggression (Kenrick et al., 2009; Miller & Maner, 2010). In the presence of an ovulating woman, we suggest that men may be primed by copulins to compete with each other and display aggression, similar to the effects of Loligo β-microsemino in squid (Cummins et al., 2011). In a series of follow-up studies, Miller and Maner (2011) had men complete an emotional perception task after being exposed to T-shirts worn by ovulating and nonovulating women. Men in the ovulating condition reported higher levels of sexual arousal and were more likely to complete a word stem to form a sexual word. They also rated the sexual interest of a female confederate significantly greater than men in the nonovulating condition. In a separately run study, Miller and Maner (2011) had participants interact with a confederate, while she was at a high-conception risk or low-conception risk. Men were accessed on how often they mimicked her body language and their risk taking in a black jack game the confederate watched. Men in the ovulating condition were more likely to mimic the confederate’s posture and make riskier decisions (Miller & Maner, 2011).

Doty, Ford, Preti, and Huggins (1975) found that on average men and women rate preovulatory and ovulatory secretions as weaker and less intense than secretions from other phases of the menstrual cycle. Cerda-Molina, Hernandez-Lopez, De la O, Chavira-Ramirez, and Mondragon-Ceballos (2013) provide evidence that men exhibit endocrine changes specifically to increased concentrations of chemicals in women’s axillary and vulvar secretions at ovulation. Axillary and vulvar scents from high fertility phases increased cortisol and testosterone levels with vulvar scents, creating a longer lasting changes. General sexual interest also increased. Luteal vulvar scents were rated as intense and unpleasant compared to the other scents. These studies as well as others presented above show that men are sensitive to high fertility and low fertility odors, but these studies do not isolate copulins as the potential chemical mechanism.

Jütte and Grammer (1997) exposed men to copulins, while having them rate the attractiveness of women’s faces. Hormonal measurements showed an increase in testosterone for men in the copulin condition. Men in the copulin condition also seemed inhibited in their ability to discriminate attractiveness, meaning they rated all of the women’s faces as significantly more attractive than controls and exhibited a decrease in variance of responses. A follow-up study replicated the hormonal findings and indicated men exposed to copulins were less cooperative in a tragedy of the commons paradigm than controls (Steinbach, Oberzaucher, & Grammer, 2012).

In our study, we causally tested whether copulin exposure increased men’s mate-guarding behavior, ratings of women’s attractiveness, and self-perceived sexual desirability. We sought to replicate Jütte and Grammer (1997) by exposing men to synthetic copulins while having them rate photographs of women’s faces. Prior research has focused on behavioral shifts and fluctuating asymmetry as subtle cues to human ovulation. Yet we know, olfaction and chemical signaling play an important role in social interactions and mating behavior in diverse animal taxa. The relevance of this in primates, specifically humans, has been discounted, as human sensory evolution has been characterized by increased optical primacy. However, a profusion of recent studies challenges this view. Our study will add to this growing body of research and try to answer the question: What functions does olfaction play, if any, in human mating psychology?

Material and Method

Participants

One hundred heterosexual men were recruited from advertisements posted around the campuses of Rutgers University, New Brunswick. The study involved deception as advertisements described the study as collecting hormonal measurements and measuring mating preferences. No hormonal measures were collected, and participants were debriefed afterward. Participants were paid US$20 upon completion of the study but were informed suspension of the study at any time would not effect their collection of the full participation payment. Demographic information, beyond age (M = 20.7, SD = 4.1) and relationship status (Single = 69%, Committed Relationship = 31%), was not collected in order to make participants feel less identifiable. This study was approved by the Rutgers University’s Institutional Review Board.

Procedure

Participants reported for a single session and were equally divided into two conditions, control and copulin. Control data were collected prior to experimental data. The composition of the synthetic copulin solution was 78.38% acetic acid, 13.21% propanoic acid, 4.94% butanoic acid, 0.76% methylpropanoic acid, and 2.14% methylbutanoic acid diluted with distilled water to a concentration of 0.08 per ml. The acid percentages
are from the concentrations of acids recorded during ovulation in Michael et al. (1975). All subsequent studies with copulins have used these concentrations (Jütte & Grammer, 1997; Steinbach et al., 2012). The solution was stored in a glass bottle at +4°C until participants entered the lab. At this time, 5 ml of the solution, or distilled water, were used to coat a gauze pad pinned to the inside of an Uline surgical mask. The solution was applied using a plastic pipette stored at room temperature. Subjects were instructed to wear the treated masks for the entirety of their participation.

**Measures: Ratings of Attractiveness**

Ten photographs of makeup-less women’s faces were used to test previous research that indicated exposure to copulins inhibits men’s ability to discriminate attractiveness in women’s faces (Jütte & Grammer, 1997). Stimuli were randomized, and participants rated each stimulus on a 5-point Likert-type scale, with 1 being not attractive and 5 being very attractive.

**Measures: Self-Perceived Sexual Desirability**

Assessment of self-perceived sexual desirability was measured by asking participants to rate on a 5-point Likert-type scale, with 0 being not very likely and 4 being definitely would, the photographed woman’s desire to have sex with them.

**Measures: Mate Guarding**

Mate guarding was assessed using a modified version of the Mate Retention Inventory (Buss, Shackelford, & McKibbin, 2008). We modified the inventory by reducing the number of questions and deleting the time frame of within the past year. The question reduction was due to time constraints. We removed Questions 4, 7, 9–13, 16, 19, 23, 25, 26, 28–33, and 36 as we thought these would show the least variance between conditions. The original time frame was eliminated and instead we prompted participants to think of how they behaved in any serious relationship over their lifetime. We thought this would give us a more accurate measure of mate-guarding behavior between conditions as our sample size was too small to analyze differences between single men and men in relationships (see the Section Limitations).

**Results and Discussion**

**Mate guarding**

We calculated a mate-guarding score by averaging responses on our modified version of the Mate Retention Inventory; the modified version had good internal consistency, α = .82. We then analyzed this using a between-subjects t-test. There was no difference in mate-guarding scores between the control (M = 1.2, SD = 0.5) and copulin (M = 1.3, SD = 0.5) conditions, t(98) = −.66, p = .511 (see Figure 1).

We next tested if men exposed to copulins were less discriminating when rating facial attractiveness by calculating a variance across ratings for each participant; this was analyzed with a between-subjects t-test. There was no difference between the control and copulin, t(97) = −1.27, p = .209; variance across ratings were similar in the control (M = 0.72, SD = 0.39) and copulin (M = 0.81, SD = 0.39; see Figure 1), suggesting men exposed to copulins were equally discriminating when ratings facial attractiveness.

**Self-Perceived Sexual Desirability**

We analyzed ratings of self-perceived sexual desirability using a mixed-model ANOVA, with condition as a between-subject factor and the different faces as a within-subject factor. There was a significant difference between the control and copulin condition, F(1, 97) = 3.26, p = .074, partial η² = .03; facial attractiveness ratings were higher in the copulin condition (M = 2.4, SD = 0.6) than in the control condition (M = 2.1, SD = 0.6).

We analyzed ratings of facial attractiveness using a mixed-model analysis of variance (ANOVA), with condition as a between-subject factor and the different faces as a within-subject factor. There was a trending difference between the control and copulin condition, F(1, 97) = 3.26, p = .074, partial η² = .03; facial attractiveness ratings were higher in the copulin condition (M = 2.4, SD = 0.6) than in the control condition (M = 2.1, SD = 0.6).
copulin condition than in the control condition. There was no difference in variance of responses between the copulin and control condition. Although our data were trending, we do not have statistical evidence to report a replication of Jütte and Grammer (1997). This may be due to small sample size and small number of visual stimuli (see Section Limitations).

There are different hypotheses that could explain why copulins, if they do, have an effect on men’s ability to discriminate women’s attractiveness. One may take into account Anisogamy, Sexual Selection, and Parental Investment Theory, which together explain men having a low cost and high benefit from copulating with any woman may find it advantageous to detect a cue to women’s physiological status and mate with any woman that is ovulating. Thus, when exposed to the concentrations of copulins produced at ovulation, men may be placed in a mating mind-set, where all women are now attractive. A follow-up study may look at whether men respond differently to different concentrations of copulins as well as whether we can distinguish the specific acid(s) correlating to overall genetic quality and fecundability or the acid(s) acting as the olfactory cue to physiological status as suggested in the Female Quality Hypothesis (Matsumoto-Oda et al. (2003)).

An alternative way of viewing copulins is that of a signal. Women may be using copulins to signal their physiological status and manipulate men into finding them more attractive and thus of high mate quality. Future studies should also look at attractiveness ratings of full-body photographs as research suggests waist-to-hip ratio is also an indicator of conception risk (Kirchengast & Gartner, 2002). Are men exposed to copulins less discriminatory? If copulins are a signal, our finding that men under the influence of copulins rate themselves as more sexually desirable to women is quite puzzling. It may further suggest an arms race between the sexes. Perhaps women use copulins to manipulate men into finding them more attractive and as counter strategy men have adapted an increased self-perception of their own mate quality, effectively canceling out the woman’s strategy of increased attractiveness.

Other hypotheses may be that copulins are a byproduct of our shared ancestry with nonhuman primates or that copulins are a signal and a cue. Perhaps women use copulins to signal to high-quality mates or to their partner when they are ovulating to increase chances of successful copulation. In turn, low-quality mates may use copulins as a cue to women’s physiological status. Future studies may examine the differences in low-quality and high-quality men’s sensitivity to copulins and what these differences, if any, may mean.

Analyses of our data produced a null result for mate guarding. The copulin and control conditions did not differ in their amount of mate guarding. Again, this result may be due to design flaws. The majority of our participants were single (69%). In the control condition, 16 participants reported being in a committed relationship and only 15 participants in the copulin condition likewise reported being in a committed relationship. Future studies should look at the difference between men in committed relationships between conditions, but the sample size of this study was simply too small to adequately determine any relationship and thus not worth reporting. Men in relationships should utilize cues to or signals of their partner’s physiological status in order to prevent mate infidelity or coordination in timing copulation, but single men are not strongly motivated to mate guard. Although our findings on mate guarding are null, we do think it worth investigating more in future studies as our study design was a severe limitation, particularly to this finding.

As mentioned previously, our results do support the hypothesis that men exposed to copulins perceive themselves as more sexually desirable to women. Again, this raises some interesting questions that may get at the differences between signals and cues. Are women producing copulins to signal they are ovulating. If so, why did they develop this mixed strategy? Are men detecting copulins as a cue to ovulation and using this information to precisely time when to increase mate-guarding behaviors? Are copulins simply a byproduct of shared phylogeny? Research on olfactory influences of human mating behavior is underwhelming. The studies that do exist fail to differentiate between signals and cues. This discrepancy will produce vastly different interpretations of any results, and future studies will need to determine how copulins should be classified.

Limitations

The current study had a number of limitations. Participants were not asked if they smoked, were suffering from a congested nose, or had any known medical issues affecting olfactory capability. Future studies should eliminate any participants that exhibit behaviors potentially leading to olfactory loss or have any known olfactory problems.

Sample size was too small to determine any meaningful findings with regard to mate guarding and relationship status. Small sample size and small number of visual stimuli may also account for the differences in our findings and Jütte and Grammer (1997). Mate-guarding behaviors were assessed using self-report, which is invariably a limitation. Interviews or a comparison between the participant’s self-reported behaviors and how their partner scored their behaviors on the same survey, at high- and low-conception risk, may be more insightful. The use of actual sensory stimuli may also provide a better measure of mate-guarding behavior when using a random sample of men, the majority of which are single. Seeing or reading a situation and having participants record their reaction may provide more accurate information as to what actions, mate-guarding or otherwise, a participant would adopt in a given situation. A reviewer also brought to our attention that removing the time frame on the Mate Retention Inventory may also be a limitation, and future research should use a measure more sensitive to immediate experimental manipulation.

Follow-up designs should also be double blind to eliminate potential researcher and participant biases. Future studies also need to take learned association into account. Copulins could be a pheromone, or the effects of copulins may be due to a
learned association between the smell of copulins and sexual arousal. Future studies should look at the sexual history of participants as a potential mediator. Perhaps only sexually active heterosexual men are effected by copulins. Chemical communication via copulins may also be a byproduct of our shared evolution with nonhuman primates and of little importance in modern society. Follow-up designs should employ scent masking tactics to see if men are still sensitive to copulins. Modern hygienic habits and the use of personal deodorant and perfumes could negate any influence copulins may have on men’s behavior and physiology.

**Implications and Future Research**

Copulins have implications for human mate choice, behavioral strategies, infertility, and sexual coercion. Waltman et al. (1973) found that postmenopausal women show a significant decrease in concentrations of iso-butyric acid in their vaginal secretions. Future research should assess the potential of iso-butyric acid in signaling or cueing female ovulation. Future research should examine the relationship between fecundity and copulin concentrations as well as how socioeconomic status effect copulin production. Women with unrestricted sexuality may produce higher concentrations of copulins as compared to women in less favorable conditions.

Primate studies show exposure to ovulating females causes males to exhibit sexually coercive behaviors (Cerda-Molina et al., 2006). Human studies have shown synthetic copulin exposure increases men’s testosterone levels and decreases their cooperative behaviors (Steinbach, Oberzaucher, & Grammer, 2012). Thus, women may be at a greater risk of direct aggressive behaviors perpetrated by men during ovulation. And indeed studies show that women may be aware of this increased risk. Women are more risk averse at high conception risk than low conception risk (Chavanne & Gallup, 1998). Women at high conception risk, but not low conception risk, display greater handgrip strength in response to sexual assault vignettes but not in response to control vignettes (Petralia & Gallup, 2002). This could have implications for domestic violence and date rape and would be an interesting area for future research.

There has been no research looking at the effects of copulins on other women. Future research questions may include whether women show greater intrasexual aggression and anti-mate poaching behaviors when exposed to copulins. Future research may also look at the sensitivity of homosexual women to copulins. As previously mentioned, olfaction is an understudied area of human mating leaving open many questions for future research. Any finding will spawn multiple new research questions, and the interactions between these findings and known olfactory influences, like major histocompatibility, will need interpreting.

**Conclusion**

Previous research indicates exposure to copulins results in hormonal changes, inhibits male ability to discriminate the attractiveness of women’s faces, and decreases men’s cooperation (Jütte & Grammer, 1997; Steinbach et al., 2012). Our study did not replicate Jütte and Grammer (1997); however, the data were trending toward significance. Men in the copulin condition did assign a higher average attractiveness rating for each woman’s face than controls. Our mate-guarding data produced null results. We did find that men in the copulin condition rated themselves as significantly more sexually desirable to women than men in the control condition. These findings provide extremely limited evidence for copulins exerting some effect on men’s behavior. However limited, these results are significant in setting the groundwork for future studies on putative human pheromones and provide some empirical evidence for olfactory influences on human mating. There are many critics of human pheromone research and this has led to some confusion in the general public about whether humans produce and detect pheromones. Although the scope of the current study is not adequate to dispel this skepticism, as associative learning was not tested, future research will address this question. The significance of this research area extends beyond academia, as some commercial perfumes capitalize on the notion of pheromones and increasing sexual desirability. Thus, the dissemination of empirical evidence for or against the role of putative human pheromones will be vital in the future.

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