

## Subthreshold amounts of social odorant affect mood, but not behavior, in heterosexual women when tested by a male, but not a female, experimenter

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### Abstract

Previously, we have demonstrated that exposure to the endogenous steroid androstadienone has the ability to modulate women's mood in that they feel more focused [Lundstrom, J.N., Goncalves, M., Esteves, F., Olsson, M.J., 2003a. Psychological effects of subthreshold exposure to the putative human pheromone 4,16-androstadien-3-one. *Hormones and Behaviour* 44 (5), 395–401]. Here, we tested the hypothesis that androstadienone exposure would modulate participating women's mood and corresponding behavior as measured by a sustained attention task. Thirty-seven women participated in a double-blind, within-group experiment and were tested by either a female or a male experimenter. Effects on mood, psychophysiological arousal, sustained attention, and ratings of male facial attractiveness were assessed. Sensory detection of the experimental substance was rigorously controlled for by psychophysical testing. The results showed that exposure to a non-detectable amount of androstadienone modulated women's psychophysiological arousal and mood in a positive direction but did not change attention performance or rating of facial attractiveness. Moreover, mood effects were only evident when an experimenter of the opposite sex conducted the testing. This suggests that social context is important for mood effects of androstadienone exposure in women.

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Pheromones were first defined almost half a century ago by Karlson and Lüscher as "... substances which are secreted to the outside by an individual and received by a second individual of the same species, in which they release a specific reaction, for example, a definite behaviour or a developmental process" (Karlson and Lüscher, 1959). Although still disputed, the notion of chemical communication among humans has gained increasing support in recent literature. Recent studies on the existence of human pheromones have mostly focused on endogenous androgens present in human sweat. Several such compounds have been proposed as putative pheromones, but singled out as the most likely candidate to date is the endogenous steroid 4,16-androstadien-3-one [(androstadienone); Bensafi et al., 2003;

Jacob et al., 2001a; Jacob and McClintock, 2000; Kovacs et al., 2004; Savic et al., 2001]. Androstadienone is a member of the family of odorous 16-androstenes and can, among others, be found in male axillary secretion with a mean value of 228 pmol/total axillary hair weight (Nixon et al., 1988). Androstadienone is also found in women, although generally in much smaller concentrations (Brooks-bank et al., 1972).

Since androstadienone is most abundant in males it is considered to be a putative male human pheromone. Support for that notion can be found in the literature showing that women seem to react stronger and in a more consistent way than men to exposure (Bensafi et al., 2004, 2003; Jacob et al., 2001a; Jacob and McClintock, 2000). The most consistently demonstrated effect in the above reported studies is that androstadienone exposure modulates mood. Interestingly, one study reported no such mood effect when exposure was

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paired with a neutral stimulus (Bensafi et al., 2003). However, the social context of the test situation proved to be of crucial importance since pairing androstadienone exposure with an emotionally arousing stimulus did modulate mood of the study participants (Bensafi et al., 2004). Moreover, Jacob et al. (2001a,b) found that the presence of a man during exposure to androstadienone was necessary to elicit an autonomic reaction in women. This suggests that in order for androstadienone exposure to elicit robust responses in women, the presence of an ecologically relevant context may be necessary. That ecologically relevant cues may be needed to facilitate pheromonal responses is indeed seen in the mammalian literature (Izard, 1983). However, so far, no candidate pheromone compound has been able to fulfill the original definition's most stringent requirement of being able to release a definite behaviour.

To ascertain whether demonstrated effects are induced by pheromone-like processes rather than by differences in perception between experimental and control stimuli, most previous studies have either compared intensity ratings of experimental and control odors (Bensafi et al., 2004, 2003; Savic et al., 2001) or used a masked near-threshold concentration and compared post-test verbal descriptors in an attempt to control for perceptual differences between experimental and control stimuli (Jacob et al., 2002, 2001a; Jacob and McClintock, 2000). However, lack of differences in intensity ratings does not necessarily mean that odors are qualitatively indiscriminable, and hence they could still give rise to different associations or cognitive processes. Studies have shown that both memory associations and differences in perceived quality of odors are capable of changing mood, autonomic nervous system (ANS) tone, and cortical responses (Alaoui-Ismaili et al., 1997; Anderson et al., 2003; Robin et al., 1999; Savic et al., 2000). Moreover, verbal descriptor tests depend heavily on participants' episodic memory and may not rule out the possibility that effects are due to conscious awareness of the substance of interest (Lundstrom et al., 2003b). We think that in understanding potential pheromonal processing in humans, a fundamental step is to monitor the effects of conscious perception as well as discriminatory performance.

Exposure of women to a subthreshold amount of androstadienone has been demonstrated to induce a heightened feeling of being focused.<sup>1</sup> In comparison with a perceptually indistinguishable control odor, a weak but persistent feeling of being more focused was obtained in two consecutive experiments (Lundstrom et al., 2003a). The authors speculated that androstadienone activated an attention-related mechanism. Recently, Gulyas et al. (2004) found further tentative support for this notion in that androstadienone exposure in women activated cortical regions associated with attention.

To investigate whether exposure to a subthreshold putative human pheromone would modulate attention performance, we exposed women to androstadienone while performing a task tapping sustained attention. To demonstrate that potential effects in this study were not due to conscious differences in perception, the participants' ability to correctly discriminate between experimental and control solutions was assessed with a psychophysical test. To test whether potential behavioral effects of exposure to androstadienone on the attention task would require being paired with ecologically valid contextual cues, we employed two experimenters of opposite sex. Recently, studies using sweat derivate compounds have indicated that they are able to alter viewer's perception of faces (Cornwell et al., 2004; Kovacs et al., 2004). To test whether androstadienone in fact holds the ability to modulate women's percept of male faces as indicated by Cornwell et al. (2004), the participating women rated perceived attractiveness of pictures of unknown males.

In the current study, we expected that androstadienone exposure would enhance positive mood and modulate ANS tone in the tested women, but especially so when a male experimenter conducted the testing. A specific hypothesis was that androstadienone exposure would once again enhance women's feelings of being *focused* and, consequently, performance in a sustained attention task.

## 1. Method

### 1.1. Participants

Thirty-seven women with a mean age of 25.35 (S.D. = ±4.63) years with a normal menstrual cycle were recruited through posters on the campus area. All participants reported absence of nasal congestion and infection, olfactory dysfunctions, use of tobacco products, and use of any hormonal substances, including oral contraceptives, during the last 6 months. All described themselves as heterosexual. Based on self report of menstrual onset, four participants were deemed to be tested during menses (days 1–5 from menstrual onset), 14 participants in the follicular phase (days 6–14), and 19 in the luteal phase (days 15–35) of their menstrual cycle. To assess potential difference in menstrual phase between participants tested by a different experimenter, a two-tailed independent Student's *t*-test with experimenter as the between group factor indicated that there was no statistical difference,  $t(35) = 0.99$ ,  $P = \text{ns}$ . There were no significant effects of menstrual cycle phase for any of the dependent measures. Further, participants were kept naive to the experiment's main hypotheses and the identity of all stimuli involved. Participants were first informed about the main hypotheses after the completion of the whole experiment. In response to an open question in the end of the experiment, none of the participants revealed any knowledge about the true aims of the experiment.

<sup>1</sup> The word *focused* in Swedish (*fokuserad*) relates to a state of being attentive rather than being focused at a single object or individual.

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