THE EFFECTS OF ANDROSTADIENONE, A HUMAN PHEROMONE, ON FACIAL EMOTIONAL RESPONSES, FACIAL EMOTION RECOGNITION AND GENDER RECOGNITION

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Summary

Pheromones, chemical substances that are released by organisms to influence or communicate with their conspecifics, are an important source of influence on the social behaviours in a wide range of species. Recent research has identified androstadienone as a human pheromone. The present study investigates the effects of androstadienone on three social behaviours: facial emotional responses, facial emotion recognition and gender recognition and how the effects of androstadienone on these variables are moderated by sex of the faces shown to the participants. One hundred and twenty one participants were exposed to either the androstadienone or a control solution in a randomised double blind placebo controlled experiment. The participants completed two tasks: facial emotion recognition task and gender recognition task. The facial emotion recognition task had dynamic morphs of faces changing from a neutral expression to a happy or angry expression. The gender recognition task had faces change from an androgynous looking to a masculine or feminine looking face. Two dependent variables were measured for each task: the intensity threshold required to recognize the emotion or gender and recognition accuracy. Facial EMG was also measured at the corrugator supercilii (frowning) and zygomaticus major (smiling) muscle regions to assess the participants' facial emotional responses during the emotion recognition task. Results showed that androstadienone muted facial emotional expressions towards male targets, increased women's accuracy in recognizing male expressions of anger and decreased the intensity threshold required to recognize female faces. The results support the role of

androstadienone in influencing social behaviours. Limitations were also discussed.

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CHAPTER 1

Introduction

Social behaviour is an important aspect for many organisms. A wide variety of insects and mammals spend considerable amount of time engaging in social interactions with their conspecifics or other species. Such social behaviours often have important survival or reproductive consequences; certain (i.e., mate-seeking) behaviours may increase the chances of finding a mate. Social behaviours that aid in the formation of coalitions can increase the likelihood of securing food via group hunting, enhance an offspring's likelihood of survival through cooperation in child-rearing or provide better surveillance of the surroundings for any impending danger (i.e. predators).

For many insects and mammals, one important source of influence on social behaviours is pheromones. Pheromones are defined as chemicals released by an organism that influence the behaviours, physiology or development of a conspecific (Karlson & Luscher, 1959). Pheromones have been found to increase sexual or aggressive behaviours in several insect species (e.g. Vogt and Riddiford, 1981; Svetec and Ferveur, 2005). Boars produce a pheromone in their breath that causes sows to adopt lordosis that facilitates mounting by the boars (Gower, 1972). Female rabbits release a pheromone that causes their infants to begin suckling (Schaal, Coureaud, Langlois, Ginies, Semon & Perrier, 2003).

Given the importance of pheromones in the social behaviours of many species, questions remain as to whether pheromones exist in humans and how they affect human social behaviour (Hays, 2003; Wysocki and Preti, 2004). Androstadienone has been suggested to be a potentially important human pheromone. In men, androstadienone is found in apocrine sweat (Gower, Holland, Mallet, Rennie & Watkins, 1994; Labows, 1988), peripheral plasma (Brooksbank, Cunningham & Wilson, 1969; Brooksbank, Wilson and McSweeney, 1972; Fukushima, Akane, Matsubara & Shiono, 1991), semen (Kwan, Trafford, Makin, Mallet and Gower, 1992) and axillary hair (Nixon, Mallet & Gower, 1988; Rennie, Holland, Mallet, Watkins & Gower, 1990). In women, androstadienone is found in apocrine sweat (Gower et al., 1994). It is also found in the peripheral plasma, but in lesser quantities compared to men (Brooksbank, Wilson and McSweeney, 1972). Androstadienone, in minute concentrations and even when its odour is masked, has been found to cause significant changes in a number of variables, such as mood, physiology and behaviour (e.g. Jacob & McClintock, 2000; Jacob, Garcia, Hayreh & McClintock, 2002; Lundström & Olsson, 2005; Saxton, Lyndon, Little & Craig Roberts, 2008).

However, a lot remains to be understood about the functions of androstadienone and how it affects social behaviours as the number of behavioural studies is limited and some of the results are inconsistent. Some researchers suggest that it may function as a mating pheromone (Cornwell, Boothroyd, Burt, Feinberg, Jones, Little, Pitman, Whiten & Perrett, 2004; Saxton et al., 2008) while others suggest that it may serve to influence a wider range of social functions (Hummer and McClintock, 2009). In order to better

understand the functions of androstadienone, the present study looks at its effects on social behaviours. Social behaviour is a complex construct to assess. Amidst the multitude of relevant variables, the present study examines three: facial emotional responses, recognition of facial emotional expression in others, and recognition of gender in faces.

Facial emotional expressions, facial emotion recognition and gender recognition are important social behaviours

Facial emotions play important roles in social interactions (Ekman, 1974). They communicate one's emotional states (Ekman, 1974), behavioural intentions (e.g. aggression; Fridlund, 1994) and attitudes (e.g. interpersonal attraction or preference; Hazlett & Hoehn-Saric, 2000; Cacioppo, Petty, Losch & Kim, 1986). They also communicate information about the external environment, such as alerting others about any external threat or opportunities (e.g. Klinnert, Emde, Butterfield & Campos, 1986; Sorce, Emde, Campos, Klinnert, 1985).

Facial responses towards other's facial emotional expressions are purported to facilitate affiliation and social coordination (Lakin, Jefferis, Cheng & Chartrand, 2003). Research shows that a person's facial emotional responses, measured using facial electromyographic (facial EMG) techniques, can be evoked by presenting still photos or dynamic animations of facial expressions to them (e.g., Dimberg, 1982; Dimberg & Lundqvist, 1988; Hess, Philippot, & Blairy, 1998; Rymarczyk, Biele, Grabowska, & Majczynski, 2011; Sato, Fujimura, & Suzuki, 2008). For example, participants tend to show greater activation in the muscles that lift up the edge of the mouth to form a

smile (zygomaticus major) when shown a happy face compared to an angry face while they tend to show greater activation in the muscles that furrow the eyebrow into a frown (corrugator supercilii) when shown an angry face compared to a happy face (e.g. Dimberg, 1982; Dimberg & Lundqvist, 1988; Hess, Philippot, & Blairy, 1998; Rymarczyk, Biele, Grabowska, & Majczynski, 2011; Sato, Fujimura, & Suzuki, 2008). Although facial responses towards the facial emotional expressions of others were initially thought to be a pure motor mimicry process (i.e., smiling when seeing a happy expressions and frowning when seeing an angry expression; Hatfield, Cacioppo, & Rapson, 1993; Hatfield, Cacioppo, & Rapson, 1994), research has shown that such facial responses are affected by emotional context, which suggests the involvement of affective evaluation (Moody, McIntosh, Mann & Weisser, 2007). Chartrand and Bargh (1999) also showed that imitating our interaction partner increases their liking for us. Facial responses to the facial emotional expressions of others have also been linked to empathy (Décety & Chaminde, 2003; Iacoboni, 2005). Individuals with high self-reported empathy showed increased facial responses to emotional facial expressions, whereas individuals with low self-reported empathy showed incongruent facial responses instead (i.e. increased zygomaticus response to angry faces; Sonnby-Borgström, Jönsson, & Svensson, 2003).

Given the social communicative functions of facial emotional expressions, it is important for individuals to be able to recognize the emotional expressions of their interaction partners. Recognizing the facial expressions of our interaction partners allows us to decide how to respond to them. For example, using different arm movements (arm flexion and arm

extension) as measures of approach-avoidance behaviours, studies find that participants show a faster approach response (arm flexion) when shown a happy face and a faster avoidance response (arm extension) when shown an angry face (Rotteveel & Phaf, 2004). Recognizing the facial expressions of our interaction partners also allows us to decide how to respond to the environment. For example, infants rely on the facial expressions of adults when deciding whether to approach a foreign toy or a visual cliff (Klinnert, Emde, Butterfield & Campos, 1986; Sorce, Emde, Campos, Klinnert, 1985). They tend to approach the toy or visual cliff when the adults show a happy expression and tend to avoid the toy or visual cliff when the adults show a fearful expression. Individual difference in facial emotion recognition is also related to a number of important social outcomes. Better facial emotion recognition predicts higher popularity among peers in children (Boyatzis & Satyaprasad, 1994), better parents-reported social competence in preschoolers (Philippot & Feldman, 1990), better self-reported relationship well-being in adults (Carton, Kessler, & Pape, 1999) and better payoffs in an economic negotiation game (Elfenbein, Foo, White, Tan, & Aik, 2007).

Many studies have examined the accuracy of detecting the facial emotional expressions of others in a categorical manner. That is, a prototypical emotional expression is shown and a participant is asked to identify it (e.g. Ekman 60 Faces Test; Young, Perrett, Calder, Sprengelmeyer, & Ekman, 2002). However, the present study is also concerned about the intensity of facial emotional expression of others that participants require to identify them accurately. Facial emotional expressions are dynamic displays that can range from the extremely subtle to obvious (Ekman & Friesen, 1978).

Therefore, it is reasoned in the present study that being able to recognize more subtle facial emotions makes us more sensitive to the facial emotional cues of others and increases the likelihood of responding appropriately to our interaction partners or the environment. The extent to which subtle facial emotions can be detected by observers is referred to as the intensity threshold for the detection of facial emotional expressions in others (Montagne, Kessels, Frigerio, De Haan, & Perrett, 2005; Venn, Gray, Montagne, Murray, Burt, Frigerio, Perrett, & Young, 2004).

Apart from facial emotional expressions, gender or sexually dimorphic facial features are also important cues involved in social interactions. In men, the jaws, chins and cheeks are bigger; the eyes are smaller but more deeply set and the brow ridges are more pronounced compared to women (Penton-Voak, Jones, Little, Baker, Tiddeman, Burt, & Perrett, 2001; Thornhill & Gangestad, 1996). Such sexual dimorphic facial cues aid gender recognition and gender identification of others affects the nature of social interactions. For example, interacting with the same-sex person could elicit intrasexual competition while interacting with a person of the opposite sex might elicit a potential mating opportunity. In addition, the formation of same-sex coalitions for “defense, aggression and war” among men and for tending and befriending among women (Taylor et. al, 2000), also requires the accurate identification of gender in others.

Sexual dimorphic facial characteristics also provide information on traits such as physical attractiveness, which can be a cue for ‘good genes’, (Penton-Voak & Perrett, 2000; Penton-Voak, Perrett, Castles, Kobayashi, Burt, Murray & Minamisawa, 1999; Perrett, May & Yoshikawa, 1994) and

aggressiveness (Carre & McCormick, 2008), which may affect whether and how we interact with another person.

Androstadienone may affect facial emotional expressions, facial emotion recognition and gender recognition

Research suggests that androstadienone may affect a person's facial responses to the facial emotional expressions in others, facial emotion recognition and gender recognition. Brain activation studies showed that smelling androstadienone activates regions involved in these social behaviours. Savic and colleagues found that androstadienone increased activation in the amygdala, hypothalamus and inferior frontal gyrus in women only (Savic, Berglund, Gulyas & Roland, 2001). The amygdala is implicated in the evaluation of emotional valence and facial emotional expressions (Hariri, Tessitore, Mattay, Fera & Weinberger, 2002). The hypothalamus is implicated in sexual responses (Karama, Lecours, Leroux, Bourgouin, Beaudoin, Joubert, et al., 2002; Takahashi, Matsuura, Yahata, Koeda, Suhara, & Okubo, 2006) as well as the autonomic responses that drive emotional responses (Sapolsky, Romero & Munck, 2000). Gulyas and colleagues also found that androstadienone increased activations in the superior temporal gyrus and the fusiform gyrus in women (Gulyas, Keri, Sullivan, Decety & Roland, 2004). The superior temporal gyrus is associated with the recognition of facial emotional expressions (Haxby, Hoffman & Gobbini, 2000) whereas the fusiform gyrus is associated with the recognition of facial identity, including gender (Kanwisher, McDermott & Chun, 1997; Sergent, Ohta & MacDonald, 1992). However, the brain activation studies reviewed so far have only looked at the effects of

androstadienone where the participants were resting while being exposed to the substance. Therefore, they do not provide conclusive evidence of the effects of androstadienone on behaviour.

A number of behavioural studies have looked at the effects of androstadienone on mood. The results showed that the effects of androstadienone depend on the sex of participant and/or sex of the person that the participants interacted with (i.e., the experimenter). While three studies found that androstadienone tend to affect mood depending on the sex of the participant, it is unclear whether its effects are specific in increasing or decreasing positive and/or increasing or decreasing negative mood (Bensafi, Tsutsui, Khan, Levenson & Sobel, 2004; Jacob & McClintock, 2000; Villemure & Bushnell, 2007). For example, while Jacob and McClintock (2000) found that androstadienone increased positive mood in women but decreased positive mood in men, Bensafi et al. (2004) found that androstadienone increased positive mood and decreased negative mood in women but had no effects on men.

Two studies found that the effects of androstadienone on women depended on the sex of the experimenter. Androstadienone increased women's positive mood when the experimenter is male (Jacob, Hayreh & McClintock, 2001; Lundström & Olsson, 2005).

The current study provides a further investigation of the effects of androstadienone on mood by looking at facial responses to facial emotional expressions. The effects of androstadienone on mood responses might be more relevant and consistent when mood is operationalized as facial emotional responses rather than verbal self-report (see Izard, Kagan &

Zajonc, 1984 for a review of the different domains of emotional response). Studies indicate limited language ability among other primates (e.g. chimpanzees) (e.g. Premack, 1971; Savage-Rumbaugh, Shanker, & Taylor, 1998) but similar social functions for facial emotional expressions between humans and other human primates (Darwin, 1872), thus suggesting that facial emotional expressions are likely to predate the evolution of language in humans and hence, constitute another source of social communication. Moreover, self-reported mood is only modestly correlated to facial emotional responses (Larsen, Norris & Cacioppo, 2003). Hence, it is unclear how robust the results are when mood is measured using facial electromyography.

In the case of facial emotion and gender recognition, there is a paucity of studies looking at the effects of androstadienone on these variables. One study that showed that 5α-androstenone, a derivative of androstadienone, sprayed in a room, can reduce the threshold intensity required to identify the gender of faces (Kovacs, Gulyas, Savic, Perrett, Cornwell, Little, Jones, Burt, Gal & Vidnyansky, 2004). However, different substances, even when derived from the same source or from each other can have different effects (Jacob, Garcia, Hayreh & McClintock, 2002). My study aims to fill in this gap in the current research literature. Given that the effects of androstadienone on mood may be moderated by sex of participant and/or sex of the person that the participants interact with (i.e. experimenter), the present study also explores whether the effects of androstadienone on facial emotion and gender recognition depended on sex of participant and/or sex of the face presented (Target's sex).

Hypotheses

1. The effects of androstadienone on the participants' facial responses (corrugator and zygomaticus) to the target's facial emotional expressions would be moderated by target's sex and/or participant's sex. This hypothesis is non-directional.

2. Androstadienone would affect facial emotion recognition. The current research literature permits the following directional hypotheses to be tested:

2a. Androstadienone would lower the intensity threshold required to identify the facial emotion displayed.
2b. Androstadienone would increase the accuracy of identifying the facial emotion displayed.

3. Androstadienone would affect gender recognition. The current research literature permits the following directional hypotheses to be tested:

3a. Androstadienone would decrease the intensity threshold required to identify the gender of a face.
3b. Androstadienone would increase the accuracy of identifying the gender of a face.

4. The effects of androstadienone on facial emotion recognition and gender recognition would be moderated by target's sex and/or participant's sex. This hypothesis is non-directional.

CHAPTER 2

Method

Participants

Sixty one men, M_{age} (*SD*) = 21.88(1.36), and 60 women, M_{age}(*SD*) = 19.95(1.38), from the National University of Singapore participated in this study in exchange for research participation credits. All participants were non-smokers, were not taking any drugs or hormonal supplements (i.e. oral contraceptives) and did not have any current or previous nasal conditions (i.e. flu, nasal congestion or nasal surgery) that would adversely affect their olfactory functioning. Participants were required to refrain from wearing any scented products during the experiment. Male participants were also required to shave off any facial hair.

Materials

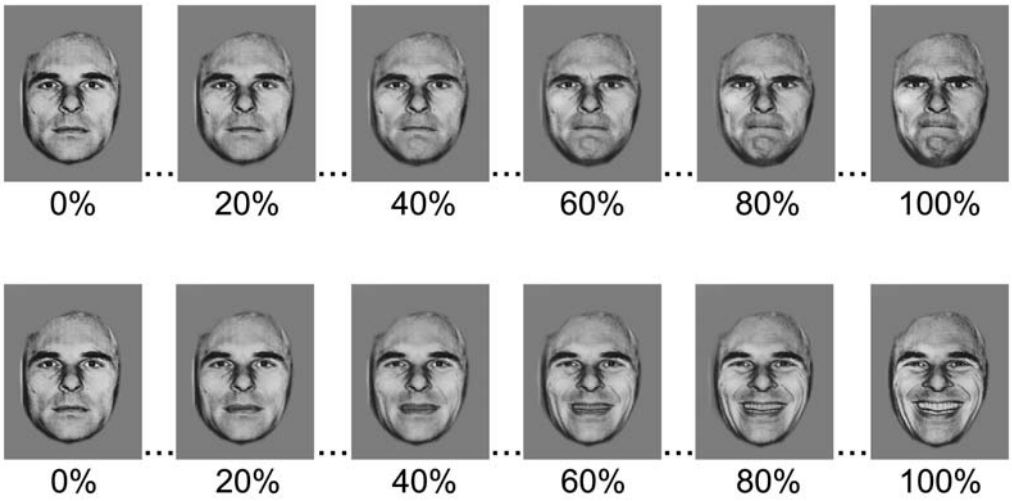
Androstadienone and control solution. The androstadienone and control solutions were prepared according to the procedures reported in previous studies (Jacob & McClintock, 2000; Jacob, Garcia, Hayreh & McClintock, 2002; Saxton, Lyndon, Little & Craig Roberts, 2008). Crystallized androstadienone (Steraloids Inc., Newport, RI) was dissolved in a carrier solution containing 99% propylene glycol (Sigma-Aldrich Co., Singapore) and 1% clove oil (Sigma-Aldrich Co., Singapore) to create a mixture with an

androstadienone concentration of 0.00025M. Clove oil was included in the carrier solution in order to mask the odour of the androstadienone (Jacob & McClintock, 2000). The control solution consists of just the carrier solution. The androstadienone and control solutions were stored in separate Eppendorf tubes. Each tube contained 260μl of either the androstadienone or the control solution.

Discrimination task. Even with the clove oil to mask the odour of androstadienone and the low concentration of androstadienone used, it has been shown that a small number of participants can still discriminate between the androstadienone and control solutions (e.g., Lundström, Gonçalves, Esteves, & Olsson, 2003). Therefore, a discrimination task was set up to identify such individuals so as to remove them from the analyses. The androstadienone and control solutions were stored in 15ml glass bottles, each bottle containing 12ml of either solution. A total of nine bottles consisting of three androstadienone and six control solutions were created. These bottles were grouped into three sets (one androstadienone and two control in each set).

Dynamic facial emotion stimuli. Photos of the faces of two male and two female individuals displaying neutral, angry and happy expressions were chosen from the Facial Expressions of Emotion - Stimuli and Tests (FEEST; Young, Perrett, Calder, Sprengelmeyer, & Ekman, 2002). These photos were originally from the Pictures of Facial Affect series (Ekman & Friesen, 1976). Using the free morphing software Winmorph (version 3), the neutral photos were morphed with the angry and happy photos to create dynamic facial expressions stimuli where the face gradually changes from a neutral (0%) to

an angry expression (100%) or from neutral (0%) to a happy expression (100%; Figure 1).



Note. This figure was produced, with permission, using copyrighted stimuli belonging to the Paul Ekman Group, LLC. No part of this figure may be reproduced without permission of the copyright owner.

Figure 1. An example of dynamic facial emotional stimuli of faces changing from neutral to angry (top) and from neutral to happy (bottom).

Dynamic gender stimuli. Three steps were taken to create dynamic gender stimuli of faces morphing from androgyny to a male face or from androgyny to a female face. Firstly, photos of highly masculine male faces and highly feminine female faces were selected from a pool of photos. Full frontal photos of Caucasian men and women, aged 18-30, displaying neutral expression were taken from 4 databases: The face database from the Center of Vital Longevity (Minear & Park, 2004), Put face database (Kasiński, Florek, & Schmidt, 2008), Fei face database (Thomaz, 2006) and Color Face Recognition Technology database (Philips, Moon, Rizvi & Rauss, 2000; Phillips, Wechsler, Huang, Rauss, 1998; Phillips, Moon, Rizvi, Rauss, 2000). Faces with excessive facial hair, make-up or hair obscuring the forehead were

taken out from the pool, leaving a total of 381 photos (230 males and 151 females) for the selection. For standardization purpose, the photos were rotated using Adobe Photoshop CS3 (version 10.0.1) so that the pupils were on a horizontal plane. These photos were then resized so that the inter-pupillary distance of all faces is standardized to 100 pixels and the positions of the pupils for these faces were aligned to be at the same position on the canvas. Several facial measurements (in pixels) were then taken (Figure 2): face length (a), lower face length (eye to chin) (b), distance between inner edges of eyes (c), distance between outer edges of eyes (d), cheekbone width (e), jaw width (f) and eyebrow height from three different positions for each eye (g1-6). Five computations that have been found to differentiate male and female faces (Penton-Voak, Jones, Little, Baker, Tiddeman, Burt, Perrett, 2001) were then computed: lower face length/face length (b/a), cheekbone width/lower face height (e/b), eye size ((d-c)/2), mean eyebrow height (Mean(g1-g6)) and cheekbone prominence (cheekbone width/jaw width (e/f)). The computations were then converted to Z scores and a composite score of overall masculinity was computed using the formula: Z(lower face length/face length) - Z(face width/lower face height) - Z(eye size) - Z(mean eyebrow height) - Z(cheekbone prominence). The higher the score, the more masculine a face is. Based on this score, the 64 most masculine male faces and 64 most feminine female faces were selected.

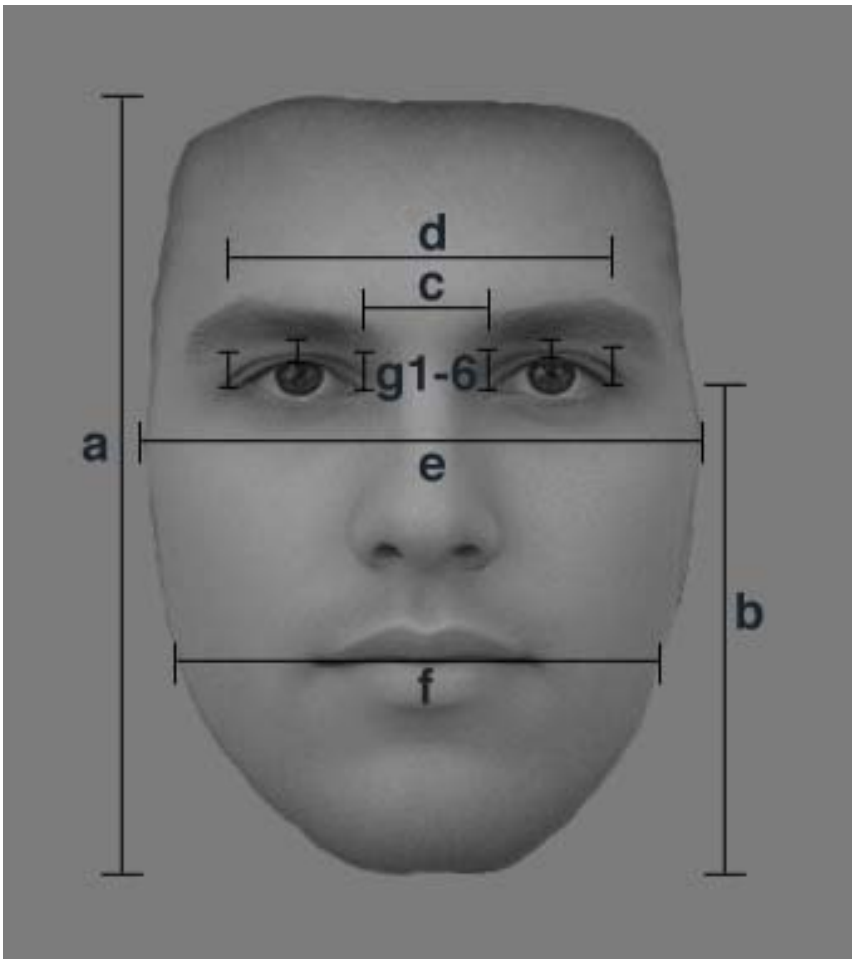


Figure 2. Example of the measurements taken from the faces to generate a composite measure of masculinity.

Secondly, average faces were created within each gender. The 64 selected faces within each gender were randomly assigned into four groups of 16. The 16 faces were then morphed to create an average face of that gender. The procedure to create an average face derived from 16 faces is as such: Each individual face is first paired with another, forming eight pairs of faces. Winmorph is then used to create a face with the average shape and skin tone for each pair of faces. This creates eight average faces that were derived from each pair. The eight resultant faces were then randomly paired again, forming four pairs of faces, and morphed to create four average faces

derived from these pairs. This procedure continues until an average face derived from the 16 faces was formed.

Thirdly, the dynamic gender morphs were created for each randomly paired average male/female faces. An androgynous face was first created by averaging the pair of average male/female faces. The androgynous face is then morphed with its “parent” average male face or “parent” average female face to create the two gender morphs. For instance, blending the parent male face with the androgynous face creates a more masculine version of the androgynous face while blending the androgynous face with a parent female face increases its facial femininity. One slight difference from the emotional recognition task is that the end point of the morph is extended beyond 100% to create a hyper-masculinized/hyper-feminized face by exaggerating the differences between the androgynous face and the average male/female faces respectively. This was done because averaging the faces reduces the masculinity of male faces and femininity of female faces. For example, an averaged male face is less masculine than the individual male faces used to create the averaged male face (Little & Hancock, 2002). Therefore, as done in previous published research (e.g., Frigerio, Burt, Montagne, Murray, Perrett, 2002), the sexual dimorphism of the faces are exaggerated. Thus, the dynamic gender morphs change from 0 (androgyny) – 130% (hyper-sexualized; see Figure 3). Eight dynamic gender morphs, four male and four female faces, were created as test stimuli in total.

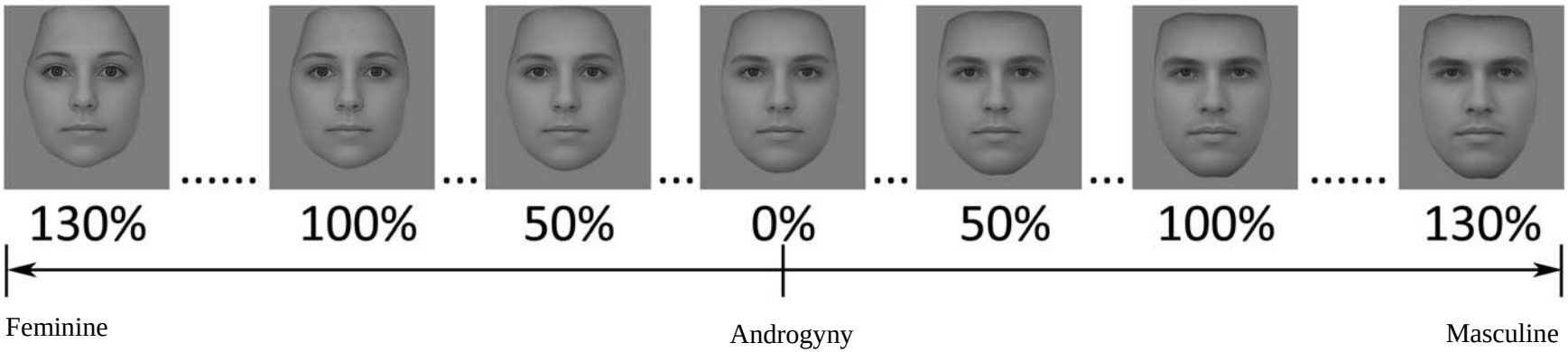


Figure 3. Example of a pair of male/female average faces (100% at each side) morphed to create two dynamic stimuli changing from androgyny (0%) to the male face (right) or from androgyny to the female face (left). The end points are extended to 130% by exaggerating the difference between the androgynous face and the 100% faces.

Physiological measurements

Facial electromyography (EMG). Using 4mm wide Ag/AgCl reusable electrodes, facial EMG measurements were taken at two sites: the left zygomaticus major and the left corrugator supercilii. At each site, two adjacent electrodes were placed 1cm away from each other along the axis of each muscle (Fridlund and Cacciopo, 1986). The ground electrode was placed on the forehead. Data was collected using the EMG100c transducer and MP100 (BIOPAC Systems Inc, CA) at a 2000Hz sampling rate. The facial EMG signals were amplified by a factor of 1000 and a 1-5000Hz band-pass filter was used.

Procedure

To control for the effects of sex of the experimenter (e.g., Jacob, Hayreh & McClintock, 2001), a male experimenter conducted the experiment for half of the participants and a female experimenter conducted the experiment for the other half. This is a double blind study where the participants were block randomised by gender into one of the 2 (androstadienone vs control) x 2 (male experimenter vs female experimenter) between subject conditions by a third party who was not involved in the data collection. The Eppendorf tube assigned to each participant was then coded with the participant number by the third party before being handed to the experimenters. The bottles used for the discrimination task were colour-coded and the order of the bottles in each set was arranged by the third party before being handed to the experimenters. The participants were only told that the

solutions contained natural occurring substances in order to prevent any demand characteristics due to the knowledge that the solutions may contain pheromones.

The participants were tested individually in a participant room fitted with a central ventilation with pleated filters (75%-80% efficiency) that replaces the air within the room at a rate of 2-3 room changes per hour. There was also a portable HEPA filter (99.97% efficiency) that runs at a rate of 15 room changes per hour. Participants were seated in front of cathode-ray tube monitor with a mouse and a keyboard. Interactions between the experimenter and the participants were minimized.

The entire experiment was conducted over two consecutive days. Previous studies have shown that individuals exhibit circadian changes in hormonal levels and alertness that may impact their task performance (Piro, Fraioli, Sciarra, & Conti, 1973; Van Cauter, Leproult, & Kupfer, 1996; Wright, Hull, & Czeisler, 2002). Therefore, sessions on both days were conducted at the same time. On the first day, the participants first provided some basic demographic information, such as age and sex. They then completed some questionnaires investigating other hypotheses unrelated to this study. After completing the questionnaires, participants were given the discrimination task. For each trial, the participants were presented with one set of solutions containing one androstadienone and two control solution bottles. Participants had to identify the one that smelled different from the other two. The bottles were handed to the participant one at a time by the experimenter and participants were only allowed to smell each bottle once. In between bottles, there was a 20s time interval to prevent habituation to the smell of the

solutions. The three sets of bottles were rotated until each set was presented three times, making a total of nine trials.

On the second day, to prevent the participants from knowing that their facial muscular movements were being measured, they were told that the electrodes measured sweat gland activity. The sites were cleaned using alcohol swabs prior to electrode placement. After electrode placement, the experimenter applied the solution from the assigned tube to the region of the skin under the nose and above the upper lip. A break of 5mins then ensued for the pheromone to take effect (Jacob & McClintock, 2000).

The participants then proceeded to perform the facial emotion recognition task and the gender recognition task. The order of the tasks was counterbalanced between participants. For the facial emotion recognition task, the participants were first given a practice task, followed by the actual task. For the actual task, each emotion from each actor was presented twice, making a total of 16 trials. The trials were pseudo-randomized such that no more than two consecutive trials were of the same actor/gender/emotion. This was to prevent sensory adaptation to a specific actor/gender/emotion, which may influence the participants' threshold for identifying the emotions. Participants were given the freedom to rest anytime between trials. Each trial of the facial emotion recognition task consists of two parts. The first part measures the intensity threshold that participants require in order to identify the facial emotion and their recognition accuracy. Starting from a neutral expression, participants were required to increase the intensity of the facial emotion until the first point where they can identify the emotion. The option of decreasing the intensity was also made available to the participants in case

they find that they have overshot the threshold. For this part, the animation consists of a total of 51 frames. Every increase or decrease corresponds to a 2% change in intensity. After locating the point where they can identify the emotion of the face, participants were required to indicate which emotion the face was expressing.

For the second part, the participants were shown the video of the entire morphing sequence from 0 – 100%. The video runs for a total of six seconds. The first second consists of the face changing from 0 – 100% at a rate of 24 frames per second. The 100% frame then remains on screen for the next 5 seconds. The video is both preceded and followed by a 2s fixation cross. The facial EMG activities were recorded during the presentation of the video. During the videos, the experimenter would observe the participants through a one-way mirror in the adjacent experimenter room. Trials were noted if participants were found engaging in movements that would affect and confound the facial EMG data (e.g., moving of the head, yawning, coughing).

The gender recognition task uses the same procedure as the emotional recognition task. The participants were given a practice task, followed by the actual task. For the actual task, each dynamic stimuli was presented twice, making a total of 16 trials. The task was also pseudo-randomized so that no more than two consecutive trials were of the same gender or from the same male/female face pair.

Facial EMG data reduction

Data due to the participants' extraneous movements were removed. The 7sec data (1sec prior and 6sec during video presentation) was converted

to Z scores within participant and facial muscular site. The average EMG activity 1sec before the start of the video was taken as the baseline. The average activity during the 6sec video was taken as the response (see Figure 4). The participant's EMG response was then taken as the difference between the average value during the video presentation and the baseline EMG level.

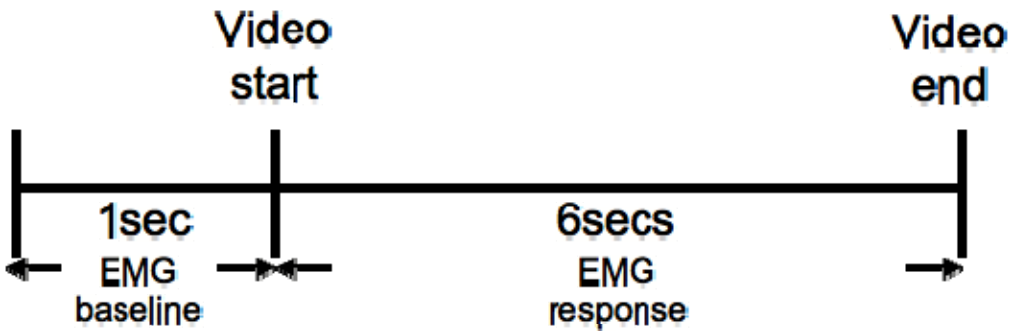


Figure 4. Example of how a 7sec EMG data is segmented into baseline (1 sec prior to video onset) and response (6sec video).

CHAPTER 3

Results

An alpha of .05 was used for the following analyses.

Discrimination task

The binomial probability of picking the androstadienone solution correctly six or more times is .042. Based on this probability, 11 participants (five men and six women; 9.09%) were deemed as being able to discriminate between the placebo and androstadienone solutions at a probability of $\leq .042$. These participants were removed from the subsequent analyses, leaving 110 participants (56 men and 54 women).

Facial EMG

After removing the data due to participants' extraneous movements, three participants had missing corrugator data and two participants had missing zygomaticus data in one or more cells and were thus removed from the respective analyses. One hundred and seven participants (54 men, 53 women) were left for the corrugator analysis and 108 participants (55 men, 53 women) for the zygomaticus analysis.

Facial EMG baseline

Table 1 presents the descriptive statistics for the baseline Z scores for each muscle group by Androstadienone and Sex of Participant.

Table 1. Mean baseline Z scores (*SD*) by Androstadienone and Sex of Participant.

	Corrugator, Z score		Zygomaticus, Z score	
	Men	Women	Men	Women
Treatment Condition	*N* = 54	*N* = 53	*N* = 55	*N* = 53
Androstadienone	.28 (.47)	.06 (.58)	.06 (.31)	.10 (.52)
Control	-.002 (.42)	.006 (.53)	.12 (.46)	-.10 (.44)

Two 2 x 2 between-design ANOVAs were conducted with either the baseline corrugator level or baseline zygomaticus level as dependent variables. The between variables were *Androstadienone* (placebo vs androstadienone) and *Sex of participant* (men vs women).

Baseline corrugator levels. The main effects of Androstadienone, $F(1,103) = 3.06$, $p = .08$, $\eta^2_{partial} = .03$, Sex of Participant, $F(1,103) = 1.15$, $p = .29$, $\eta^2_{partial} = .01$, and the interaction between Androstadienone and Sex of Participant, $F(1,103) = 1.33$, $p = .25$, $\eta^2_{partial} = .01$, were nonsignificant.

Baseline zygomaticus levels. The main effects of Androstadienone, $F(1,104) = .73$, $p = .40$, $\eta^2_{partial} = .007$, Sex of Participant, $F(1,104) = 1.20$, $p = .28$, $\eta^2_{partial} = .01$, and the interaction between Androstadienone and Sex of Participant, $F(1,104) = 2.23$, $p = .14$, $\eta^2_{partial} = .02$, were nonsignificant.

Facial EMG responses

Table 2 presents the descriptive statistics for the change Z scores for each muscle group by Androstadienone, Sex of Participant, Target's Sex and Emotion displayed.

Two 2 x 2 x 2 x 2 mixed-design ANOVAs were conducted with either the corrugator or zygomaticus responses as dependent variables. The between variables were *Androstadienone* (placebo vs androstadienone) and *Sex of participant* (men vs women) and the within variables were *Emotion displayed* (anger vs happiness) and *Target's sex* (male vs female).

Table 2. Mean Change Z scores (*SD*) by Androstadienone, Sex of Participant, Target's Sex and Emotion displayed.

	Corrugator, ΔZ score				Zygomaticus, ΔZ score			
	Androstadienone		Control		Androstadienone		Control	
Sex of participant / Target's sex and emotion displayed	Men	Women	Men	Women	Men	Women	Men	Women
	N = 27	*N* = 26	*N* = 27	*N* = 27	*N* = 27	*N* = 26	*N* = 26	*N* = 27
Male								
Angry	-.08 (.28)	-.18 (.56)	-.03 (.31)	-.03 (.40)	.03 (.34)	-.25 (.50)	-.01 (.46)	.12 (.36)
Happy	-.46 (1.17)	-.17 (.56)	-.17 (.25)	-.18 (.26)	.02 (.28)	-.18 (.71)	-.009 (.37)	.03 (.23)
Female								
Angry	-.06 (.27)	-.16 (.56)	-.07 (.35)	-.22 (.76)	-.12 (.33)	-.06 (.33)	-.03 (.49)	.08 (.26)
Happy	-.10 (.36)	-.13 (.49)	-.21 (.40)	-.13 (.28)	.03 (.31)	.05 (.21)	-.07 (.52)	.08 (.27)

Corrugator response. Hypothesis 1 was supported. There was a significant interaction between Androstadienone and Target's Sex, $F(1,103) = 3.86$, $p = .05$, $\eta^2_{partial} = .036$ (See Figure 5). Separate independent samples T-tests were conducted for the responses towards female and male targets. The effect of Androstadienone was nonsignificant for both the responses towards female, $t(105) = .67$, $p = .51$ and male, $t(105) = 1.37$, $p = .18$, targets.

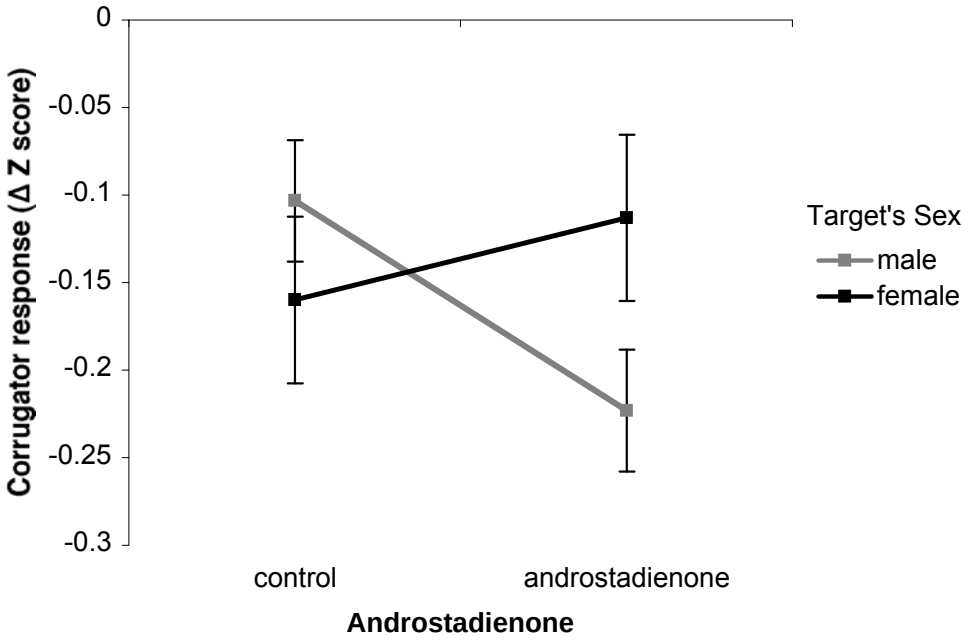


Figure 5. Corrugator response (Δ Z score) as a function of Androstadienone and Target's Sex.

Zygomaticus response. Hypothesis 1 was supported. There was a marginally significant 3-way interaction between Androstadienone, Sex of Participant and Target's sex, $F(1,104) = 3.64$, $p = .059$, $\eta^2_{partial} = .03$. Separate ANOVAS were conducted for the responses of men and women. There were no significant results for the responses of men. There was a borderline

significant interaction between Androstadienone and Target's Sex for the responses of women, $F(1,51) = 3.72$, $p = .059$, $\eta^2_{partial} = .068$. Separate independent samples t-tests showed that androstadienone caused a decrease in women's zygomaticus response towards male targets only, $t(35.54) = 2.57$, $p = .01$, (see Figure 6).

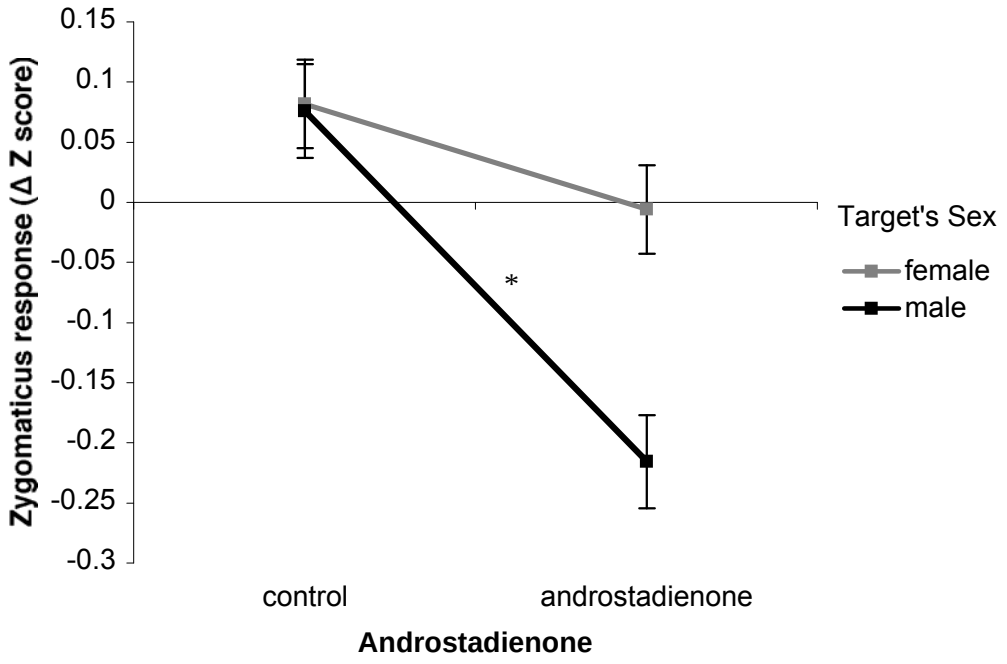


Figure 6. Women's zygomaticus response (Δ Z score) as a function of Androstadienone and Target's Sex. *$p = .01$

Facial emotion intensity threshold

Table 3 presents the descriptive statistics for the facial emotion intensity threshold by Androstadienone, Sex of Participant, Target's Sex and Emotion displayed.

Table 3. Mean Facial Emotion Intensity Thresholds (*SD*) (in percentage) by Androstadienone, Sex of Participant, Target's Sex and Emotion displayed.

	Androstadienone		Control	
Sex of participant / Target's sex and emotion displayed	Male	Female	Male	Female
	N = 27	*N* = 26	*N* = 29	*N* = 28
Male				
Angry	29.74 (7.34)	28.88 (7.16)	28.56 (8.72)	27.6 (9.44)
Happy	21.88 (8.94)	20.44 (8.46)	23.28 (11.62)	17.32 (7.98)
Female				
Angry	27.38 (7.48)	27.78 (7.00)	30.42 (12.44)	25.88 (10.46)
Happy	19.48 (6.06)	18.92 (5.44)	21.3 (7.52)	17.18 (5.34)

A 2 x 2 x 2 x 2 mixed-design analysis of variance (ANOVA) was conducted with recognition intensity (in percentage) as the dependent variable. The between variables were *Androstadienone* (placebo vs androstadienone) and *Sex of participant* (men vs women) and the within variables were *Emotion displayed* (anger vs happiness) and *Target's sex* (male vs female).

Hypothesis 2a was not supported. The main effect of Androstadienone was non-significant, $F(1,106) = .04$, $p = .83$, $\eta^2_{partial} < .001$.

Hypothesis 4 was not supported. The effect of Androstadienone was not significantly moderated by Target's Sex and/or Participant's sex.

Facial emotion recognition accuracy

Table 4 presents the descriptive statistics for the facial emotion recognition accuracy score by Androstadienone, Sex of Participant, Target's Sex and Emotion displayed.

Table 4. Mean Facial Emotion Recognition Accuracy Scores (*SD*) (in percentage) by Androstadienone, Sex of Participant, Target's Sex and Emotion displayed.

	Androstadienone		Control	
Sex of participant / Target's sex and emotion displayed	Male	Female	Male	Female
	N = 27	*N* = 26	*N* = 29	*N* = 28
Male				
Angry	87.04 (18.82)	92.31 (11.77)	87.36 (22.01)	83.93 (21.75)
Happy	100 (0)	98.08 (6.79)	99.11 (4.72)	96.55 (8.77)
Female				
Angry	100 (0)	95.83 (10.07)	96.55 (11.03)	100 (0)
Happy	98.15 (9.62)	97.12 (10.79)	96.55 (11.03)	98.21 (6.56)

A 2 x 2 x 2 x 2 mixed-design ANOVA was conducted with recognition accuracy as the dependent variable. The between variables were *Androstadienone* (placebo vs androstadienone) and *Sex of participant* (men vs women) and the within variables were *Emotion displayed* (anger vs happiness) and *Target's sex* (male vs female). Accuracy score was calculated as the number of correct trials divided by the total number of trials.

Hypothesis 2b was not supported. The main effect of Androstadienone was non-significant, $F(1,106) = 1.02$, $p = .32$, $\eta^2_{partial} = .002$.

Hypothesis 4 was supported. There was a significant 4-way interaction between Androstadienone, Target's sex, Sex of participant and Emotion Displayed, $F(1,106) = 5.39$, $p = .022$, $\eta^2_{partial} = .048$. Separate ANOVAs conducted to explore this interaction revealed a marginally significant 3-way (Androstadienone x Target's sex and Emotion Displayed) interaction for women, $F(1,52) = 4.98$, $p = .03$, $\eta^2_{partial} = .087$. Further tests revealed a marginally significant interaction between Androstadienone and Emotion Displayed for women's accuracy in identifying male facial emotional expressions, $F(1,52) = 3.39$, $p = .071$, $\eta^2_{partial} = .061$.

Androstadienone increased women's accuracy in identifying male expressions of anger (See Figure 7).

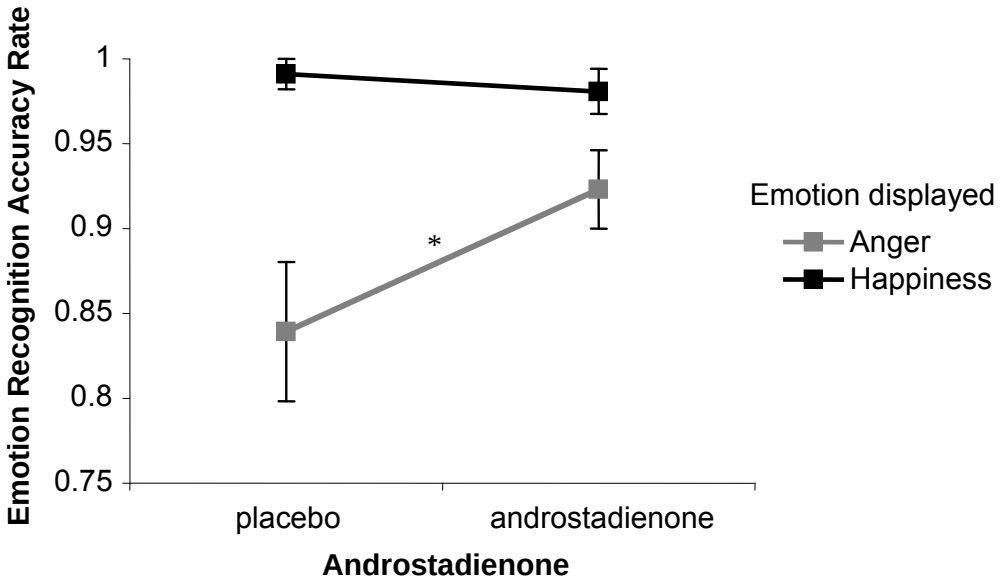


Figure 7. Women's accuracy in identifying male emotional expressions as a function of Androstadienone and Emotion Displayed. *$p = .07$

Gender recognition intensity threshold

Table 5 presents the descriptive statistics for the gender recognition intensity threshold by Androstadienone, Sex of Participant and Target's Sex.

Table 5. Mean Gender Intensity Thresholds (*SD*) (in percentage) by Androstadienone, Sex of Participant and Target's Sex.

	Androstadienone		Control	
Sex of participant / Target's sex	Male	Female	Male	Female
	N = 27	*N* = 26	*N* = 29	*N* = 28
Male	29.59 (8.66)	32.06 (10.92)	31.98 (12.09)	27.07 (8.87)
Female	32.60 (12.01)	35.00 (10.95)	39.81 (19.34)	38.38 (16.56)

A 2 x 2 x 2 mixed-design ANOVA was conducted with recognition intensity (in percentage) as the dependent variable. The between variables were *Androstadienone* (placebo vs androstadienone) and *Sex of participant* (men vs women) and the within variable was *Target's sex* (male vs female).

Hypothesis 3a was not supported. The main effect of Androstadienone was non-significant, $F(1,106) = .53$, $p = .47$, $\eta^2_{partial} = .005$.

Hypothesis 4 was supported. There was a significant interaction between Androstadienone and Target's Sex, $F(1,106) = 8.52$, $p = .004$, $\eta^2_{partial} = .074$ (see Figure 8). The simple effects revealed that androstadienone had a significant effect in reducing the threshold required to identify female faces only, $t(99.49) = 1.60$, $p = .11$.

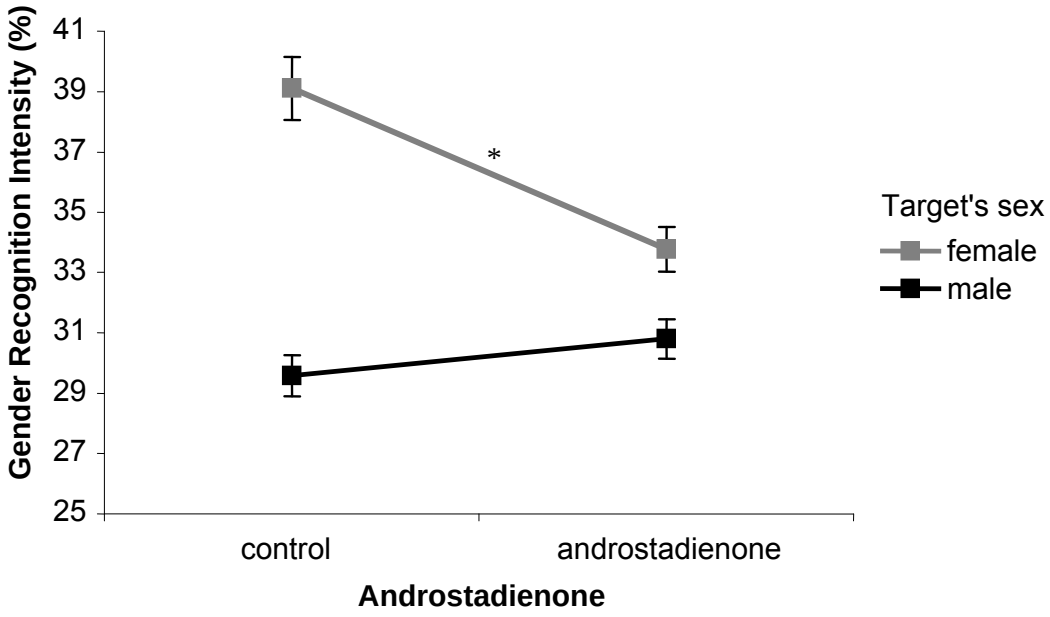


Figure 8. Gender recognition intensity threshold (%) as a function of Androstadienone and Target's Sex. *p = .11

Gender recognition accuracy

Table 6 presents the descriptive statistics for the gender recognition accuracy scores by Androstadienone, Sex of Participant and Target's Sex.

Table 6. Mean Gender Recognition Accuracy Scores (*SD*) (in percentage) by Androstadienone, Sex of Participant and Target's Sex.

	Androstadienone		Control	
Sex of participant / Target's sex	Male	Female	Male	Female
	N = 27	*N* = 26	*N* = 29	*N* = 28
Male	96.76 (6.57)	96.09 (6.96)	95.26 (7.77)	95.45 (8.85)
Female	89.51 (12.99)	88.85 (12.63)	87.50 (15.31)	90.36 (12.24)

A 2 x 2 x 2 mixed-design ANOVA was conducted with recognition accuracy as the dependent variable. The between variables were *Androstadienone* (placebo vs androstadienone) and *Sex of participant* (men vs women) and the within variable was *Target's sex* (male vs female).

Hypothesis 3b was not supported. The main effect of Androstadienone was non-significant, $F(1,106) = .16$, $p = .69$, $\eta^2_{partial} = .002$.

Hypothesis 4 was not supported. The effect of Androstadienone was not significantly moderated by Target's Sex and/or Participant's sex.

Table 7. Summary of significant results

Dependent variable	Hypothesis	Hypothesized effect	*p*-value
Facial EMG response (corrugator)	1	Androstadienone x Target's Sex	.05
Facial EMG response (zygomaticus)	1	Androstadienone x Sex of Participant x Target's sex	.059
Facial emotion recognition accuracy	4	Androstadienone x Emotion displayed x Target's Sex x Sex of Participant	.048
Gender recognition intensity threshold	4	Androstadienone x Target's sex	.004

CHAPTER 4

Discussion

A summary of the significant results is presented in Table 7. Androstadienone affected four dependent variables: corrugator responses towards male targets, women's zygomaticus responses towards male targets, women's accuracy in recognizing male expressions of anger and intensity threshold required to identify female faces in the gender recognition task.

For corrugator responses, androstadienone reduced corrugator responses towards male targets while it increased corrugator responses towards female targets to a lesser extent. Androstadienone reduced women's zygomaticus responses towards male targets. In summary, androstadienone seems to have muted facial emotional expressiveness towards male targets.

Previous studies have also shown that the effects of androstadienone on mood responses depended on sex of the participant and/or sex of the person whom they interacted with during the experiment (i.e. Jacob, Hayreh & McClintock, 2001; Jacob & McClintock, 2000; Lundström & Olsson, 2005). However, there is a difference in the pattern of the results: Jacob et al. (2001) showed that androstadienone increased positive mood in women only when a male experimenter conducted the experiment. It is unclear why there is a discrepancy in the pattern of the results. One possible explanation is that there could be other variables that moderate the interaction of androstadienone by sex of participant by target's sex. However, before one

can examine such moderators of this interaction, there are a number of methodological differences between the present study and Jacob et al.'s (2001) that has to be taken into account as possible explanations as well. Firstly, the present study measured facial emotional responses while Jacob et al. (2001) measured self-reported mood. Previous research showed that the correlation between self-reported mood and facial emotional responses is only modest (Larsen, Norris & Cacioppo, 2003), therefore the effects found when self-reported mood is used may not be replicated when facial electromyographic responses are measured instead. Secondly, the present study presented computer-generated dynamic facial emotional stimuli while Jacob et al. (2001) used human confederates. Human confederates are more naturalistic in that they represent social interaction better when compared to pictures but this is done at the expense of a lack of control for extraneous variables that might be present (e.g., nonverbal behaviour of the confederates).

While previous research on the effects of Androstadienone has used self-reported mood, the present study is the first to show that androstadienone affects facial emotional responses as well. Facial emotional responses can serve as important signals for emotions (Ekman, 1974), intentions (Fridlund, 1994), attitudes (Cacioppo, Petty, Losch & Kim, 1986) and can help draw other's attention to potential opportunities or threats in the environment (Klinnert, Emde, Butterfield & Campos, 1986; Sorce, Emde, Campos, Klinnert, 1985). Therefore, instead of facilitating social interactions, the results from the present study suggest that androstadienone may inhibit social

communications with male targets by muting facial responses towards male targets.

For emotional recognition, androstadienone caused an increase in women's accuracy in recognizing male expressions of anger. The mean accuracy scores (Table 4) show that individuals were generally least accurate at recognizing male expressions of anger to begin with when compared to the other conditions and androstadienone might serve to increase women's accuracy rate to a level similar to other emotional expressions. Androstadienone has been shown to increase activation in brain areas involved in the recognition and evaluation of facial emotional expressions (Gulyas, Keri, Sullivan, Decety & Roland, 2004; Savic, Berglund, Gulyas & Roland, 2001). But studies investigating the effects of androstadienone on facial emotion recognition using behavioural tasks have been lacking. The present study is, to the best of my knowledge, the first to show that androstadienone influences facial emotional recognition.

Apart from facial emotional responses and facial emotion recognition, androstadienone also had an effect on gender recognition by decreasing the intensity threshold required to identify female faces. However, it did not have any effects on the accuracy in identifying female faces. Therefore there were no indications of a significant trade-off in accuracy for a lower recognition intensity threshold. This is congruent with previous studies that have found that androstadienone activates brain areas associated with gender recognition such as the fusiform gyrus (Gulyas, Keri, Sullivan, Decety & Roland, 2004; Kanwisher, McDermott & Chun, 1997; Sergent, Ohta & MacDonald, 1992). However, the pattern of my results differed from that of a study that found that

5α-androstenone, a derivative of androstadienone, sprayed in a room, affected the intensity threshold required to recognize *male* faces instead of female faces (Kovacs et al., 2004). The discrepancy in the pattern of the results between this study and mine could be due to several factors. Firstly, Kovacs et al. (2004) used perceptible levels of 5α-androstenone that might have resulted in semantic priming since 5α-androstenone has a masculine odour (Amoore, Pelosi & Forrester, 1977). That is, smelling a masculine odour might prime the concept of masculinity and cause one to perform better at recognizing male faces. Secondly, different substances, in this case 5α-androstenone versus androstadienone, may simply have different effects on human social cognition and behaviour (Jacob, Garcia, Hayreh & McClintock, 2002). Therefore, further investigation is warranted.

The results on gender recognition imply that the effects of androstadienone are not specific to emotional processes (i.e., emotional responses, attention to emotional stimuli and emotional recognition; Hummer & McClintock, 2009; McClintock, 2002) and can affect gender recognition as well, as found in my study. The proposition that androstadienone affects only emotional processing is not without empirical basis; one previous study found that androstadienone enhanced participants' attention towards emotional words and emotional faces but they did not find any effects on their attention towards neutral faces (Hummer & McClintock, 2009). However, Hummer and McClintock's (2009) conclusion was derived from a comparison of attention towards faces with and without emotional expressions and did not examine the pheromone's impact on other social cognitive tasks like the present study (e.g., gender recognition). The results from the present study are in line with

the suggestion that androstadienone may affect social processes in general (Gulyas, Keri, Sullivan, Decety & Roland, 2004).

The results of the present study are in line with the proposition that androstadienone affects social behaviours. However, little is known about the evolutionary functions of androstadienone. One of the more prominent speculations is that androstadienone may function as a male mating pheromone (Cornwell et al., 2004; Saxton et al., 2008). However, it is hard to imagine how the pattern of the results in the present study can be adaptive to men in terms of sexual selection (see Andersson, 1994). Androstadienone muted facial emotional expressions towards male targets (inhibiting social communication via facial expressions), increased women's accuracy in recognizing male expressions of anger and decreased the intensity threshold required to recognize female faces, which appears to function as a cautionary cue than a male mating pheromone. It is possible that apart from signalling male mate quality, androstadienone also signalled traits such as aggressiveness and this influenced the participants' responses. Signals of male mate value have been found to not only signal male mate quality but also traits such as aggressiveness (Carre & McCormick, 2008).

Limitations of the present study

Firstly, a number of hypotheses posited were not supported. This suggests that the effects of androstadienone on human social processes may be limited. One possibility is that the effect of the pheromone manifests only during specific contexts that are relevant to the adaptive problem that it has evolved for (Williams, 1966).

Secondly, the results from the present study are contrary to that of previous studies, in particular, the finding that the effects of this pheromone were found for female faces but not male faces. This, together with the observation that a number of the hypotheses were unsupported, raises the question of whether the results are merely artifacts of Type-1 error. Although a within-subject manipulation for androstadienone would have increased statistical power, a between-subject manipulation was chosen because there could be differential carryover effects in a within-subject manipulation; participants who undergo the androstadienone condition first may associate the significant changes in their mood or behavioural responses with the some of the stimuli and this might result in carryover those effects to the control condition. Participants who experience the control condition first might not have this issue. This would introduce the issue of differential carryover effects as a confound into the study.

Thirdly, the present study did not ask participants about their sexual orientation. Previous studies have shown that the effects of androstadienone may be dependent on the sexual orientation of the participants. One study showed that androstadienone caused increased activation in the hypothalamus in homosexual but not heterosexual men (Savic, Berglund & Lindstrom, 2005). The same group of researchers also showed that androstadienone caused increased activation in the hypothalamus in heterosexual but not homosexual women (Berglund, Lindstrom & Savic, 2006). Therefore, individual differences in sexual orientation may have introduced “noise” in the data that may have masked some of the results.

Lastly, only university students were sampled for the present study. It has been suggested that the effects of androstadienone may be dependent on the age of the receiver (Saxton et al., 2008). Therefore, it remains to be determined whether the effects found for the present study are generalizable to other age groups.

Future studies

Due to the inconsistent results between the current and published studies, there is a need to further clarify the relationship between androstadienone and social processes. Presently, it is still unclear how social context moderates the effects of androstadienone on social behaviour. A better understanding of the effects of androstadienone would be served by clarifications of the moderating role of target's sex.

Future research also needs to clarify the relationship among the different variables that have been found to be affected by androstadienone. Some researchers suggested that the effects of androstadienone on emotional attention may mediate the effects of androstadienone on mood responses (Hummer & McClintock, 2009; McClintock, 2002). That is, androstadienone may affect the attention towards emotional stimuli, thus affecting individual's mood responses. But little work has been done on testing this model.

Future work could also investigate the effects of androstadienone when it is presented together with other substances that are found in the human apocrine gland. Functional pheromone may be a mixture of compounds, rather than a single one acting in isolation. Animal studies have shown that

many pheromones are made up of a mixture of multiple substances. For example, Silverstein's (1977) work on bark beetle pheromones showed that three substances that are isolated from the male beetles serve as mating pheromones to attract other beetles only when all three substances are presented together in a mixture and not when presented alone. In the male mice, two substances found in the urine are found to provoke aggressive behaviour in other male mice when presented together than when presented alone (Novotny, Ma, Zidek & Daev, 1999). Therefore, it is also possible that the function of androstadienone will manifest only when it is presented with other substances such as androstenol and androstenone (Gower et al., 1994).

Conclusion

The present study is one of the first to show that androstadienone, a human pheromone, muted facial emotional expressions towards male targets, increased women's accuracy in recognizing male expressions of anger and decreased the intensity threshold required to recognize female faces. Although the results from the present study are in line with the general proposition that androstadienone affects social behaviours, the pattern of the results from the present study are contrary to what has been found in previous studies. A number of hypotheses were also unsupported, thus suggesting that the social functions of androstadienone may be limited. Therefore more is required to understand the effects of androstadienone on social behaviours and how social context moderates the effects of androstadienone.

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Appendix A: Photos reproduction permission

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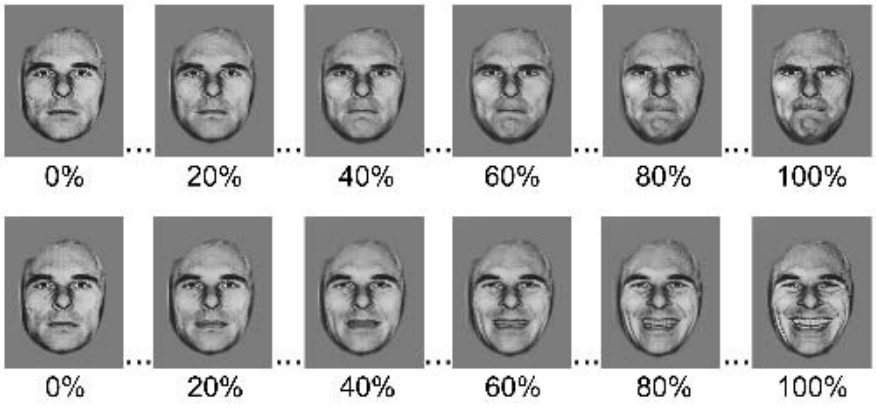
Regards,
Yongzhi



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