



# A scent of romance: human putative pheromone affects men's sexual cognition

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## Abstract

Previous studies suggest that the putative human pheromone estratetraenol affects several systems underlying human functioning and appears to activate neural systems that are known to affect sexual behavior. In this study, we investigated whether exposure to estratetraenol affects men's social cognition abilities. In the first experiment, men performed the Interpersonal Perception task while being exposed to estratetraenol and to a control solution. Men performed the task with better accuracy while being exposed to estratetraenol. This improvement was evident especially in the Intimacy category where participants evaluated romantic relationships. In a second experiment, we exposed a different sample of men to estratetraenol and to a control solution while performing a task that implicitly measured their emotional reaction to photos depicting two humans either romantically touching or not, with a control condition of two inanimate objects either touching or not. We found that the participants' emotional reaction to touch was stronger under exposure to estratetraenol. Together, these results suggest that exposure to estratetraenol may trigger a change in men's social cognition, especially in sexually related situations.

**Key words:** chemosignaling; estratetraenol; affective touch; mating behavior; sexual cognition

## Introduction

The human putative pheromone estratetraenol (EST) (estra-1,3,5(10),16-tetraen-3-ol) was first detected in women's late-pregnancy urine in the late 1960's (Thyssen *et al.*, 1968). This compound is structurally similar to estrogens and is secreted mainly by women via several body secretions, and as such it is likely to be also present in axillary sweat (Verhaeghe *et al.*, 2013). Compared with male putative pheromones such as androstadienone (4,16-androstadien-3 $\alpha$ -one), the autonomic and behavioral influences of EST on human experiences have been less extensively investigated. Previous findings demonstrate that exposure to EST affects autonomic nervous system activity, causing sustained changes in skin temperature and skin conductance (Jacob *et al.*, 2001). In addition to physiological influences, other studies showed that EST affects also psychological and emotional responses. For example, it was found that exposure

to EST increases positive mood in women and decreases it in men (Jacob and McClintock, 2000; Olsson *et al.*, 2006).

Further research assessed the behavioral influences of EST in the context of mating and sexuality. Exposure to EST has been previously linked with increased reported sexual arousal within a sexually arousing context, i.e. while watching an erotic film (Bensafi *et al.*, 2004). Also, a correlation was found between men's preference for feminine face shapes and their ratings of EST's pleasantness (Cornwell *et al.*, 2004). Exposure to EST was also shown to contribute to gender communication as it biases men's perception of dynamic point-light displays portraying the gait of walkers toward perceiving the walkers as more feminine (Zhou *et al.*, 2014). A more recent investigation found that exposure to EST biases men perception of women's emotional state, as they perceive women, but not men, as happier and more relaxed under exposure to EST (Ye *et al.*, 2019). Further support for the role of

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EST in sexual communication is apparent by its selective influence on men's electrical potentials at vomeronasal cells, electrical changes that are not produced in women's vomeronasal cells or in other olfactory epithelium cells (Monti-Bloch and Grosser, 1991). Imaging studies demonstrate that exposure to different concentrations of EST elicited brain activations in the anterior medial thalamus and in the right inferior frontal gyrus. This network has been suggested to be a homologous network to the vomeronasal system in non-human mammals (Sobel et al., 1999), which has a crucial role in the detection of pheromones and in the regulation over reproductive behavior (Luo and Katz, 2004). Collectively, the evidence demonstrates the potential role of EST in systems underlying human functioning and sexuality. It is important to note that to date, EST has not been directly detected in axillary sweat (Wyatt, 2015) and that several studies using this putative chemosignal produced conflicting effects (Pause, 2004; Ferdenzi et al., 2016; Hare et al., 2017).

In this study, we sought to further explore the role of EST in social cognition. Social cognition refers to the high-level cognitive processes that allow for complex and flexible social behavior (Adolphs, 1999). Ickes et al., (1990) found that the ability to understand accurately the subjective mental experience of other people (their thoughts and feelings) positively correlates with the perceived physical attractiveness of the target. The authors suggested that the target's physical attractiveness is an important signal that affects the individual's motivation to accurately identify the partner's mental experience. From an evolutionary standpoint, higher sensitivity to social cues signaled by opposite sex individuals may increase the chances of approaching them and the frequency of sexual encounters. If indeed EST communicates information regarding females' sexuality or readiness for reproduction, exposure to this chemosignal would increase men's mating motivation, leading to investing more effort in understanding the other's thoughts and feelings, especially those which convey sex-relevant information. This in turn might contribute to their efforts to approach potential mates. We addressed this question in two separate experiments. In the first experiment, we exposed heterosexual men to EST and control solutions while performing the Interpersonal Perception task (IPT). This task presents real-life dyadic social interactions and participants are asked to make inferences regarding the characters' relationship. This task presents real-life scenes, it has high ecological validity and it demands a wide spectrum of social cognition abilities as participants are required to cross information from multiple channels and to rely on both emotional and cognitive processes, as well as former knowledge regarding appropriate social interactions, in order to analyze and decipher the social situation properly. The task includes four categories of human social interactions (i.e. kinship, intimacy, competition and deception). We hypothesized that compared with the control solution, exposure to EST would lead to higher accuracy in judging social interactions on the IPT, especially on the intimacy category that demands participants to analyze intimate relationships and interactions between individuals.

In the second experiment, we explored participants' emotional reactions to observing the romantic touch of others during exposure to either EST or a control solution. Touch is a central part of human interactions and is used to communicate one's thoughts and feelings (Hertenstein et al., 2006, 2009). Specifically, romantic touch is one of the five expressions of love (Goff et al., 2007). Touch and love have been defined as 'indivisible' (Montagu, 1971). Types of romantic touch include kissing, cuddling, hugging, holding hands, caressing and massaging (Gulledge and

Fischer-Lokou, 2003). Collectively, romantic touch can be one of the environmental cues that suggest that there is a potential sexual opportunity. Humans acquired the ability to convert the sight of touch between others into an inner representation of touch (Gallese, 2003). This is a process that is suggested to be mediated by the visuo-tactile mirror system that integrates our own experience of touch with experiences of observed touch between others (Keysers et al., 2004). In the current experiment, we explored whether EST affects the emotional reaction to observed romantic touch of others portrayed in photos. We examined participants' emotional reactions as we asked them to rate whether they would include each of the photos in an emotional album. We hypothesized that compared with the control solution, exposure to EST would lead to an increased emotional reaction during observation of romantic touch, shown as a higher inclusion rate in an emotional album under EST compared with the control solution.

## Materials and methods

### Experiment I

**Participants.** A priori sample size estimates indicated for a power of 0.80, a minimum of 54 participants to detect a medium effect size ( $\eta_p^2 = 0.04$ ); therefore, we aimed to recruit 56 participants. To this end, 56 men were recruited via advertisements posted in the social media and at the University of Haifa. They completed an online screening questionnaire designed to assess their suitability to the current study. Subjects were 22–34 years old ( $M = 27.11$ ,  $SD = 3.25$ ) and native Hebrew speakers. All reported to have normal or corrected vision and a normal sense of smell. They further confirmed being heterosexual, non-smokers, generally healthy and free from illness in the previous few weeks. The study was approved by the University of Haifa's Ethics Committee. All participants signed an informed consent and were given credit or payment for the time. The experiment was part of a project aimed to explore the effects of exposure to chemosignals on social behavior. We also collected data concerning participants' cooperativeness that will be reported elsewhere (there is no overlap between that data and the data reported here).

**Compounds.** The experimental stimulus was a 2M EST solution (Steraloid, Inc.) diluted in propylene glycol (Sigma Aldrich; purity 99%) with 1% eugenol (Sigma Aldrich; purity 99%) as a mask odor. The control solution was prepared by propylene glycol alone with 1% eugenol. A masking odor was used to avoid possible perceptual differences between experimental and control solutions. Notably, to date, EST has not been found in women's axillary sweat (Wyatt, 2015). In the absence of studies indicating concentrations of EST in the natural environment, in this study, we used a pharmacological concentration of EST in order to ensure sufficient statistical power for obtaining existing effects. Similar stimuli have been used previously (e.g. Jacob and McClintock, 2000; Saxton et al., 2008). A previous work using similar stimuli to those used in the current study (2M EST and control), found no perceptual differences between EST and control solutions in terms of their intensity, pleasantness and familiarity (Oren and Shamay-Tsoory, 2019).

**General mood assessment.** An adapted version of the Depression Adjective Check Lists (DACL) (Lubin, 1965) was used to detect transient changes in participants' mood and the immediate effects of the environment following exposure to

the odor compounds. The DACL is a self-report instrument that consists of 32-item adjectives that describe possible mood states. This tool was used to rule out the possibility that changes in social perception accuracy were a result of general changes in mood.

We selected from the DACL list a total of eight adjectives: four indicating a positive mood (e.g. happy, calm) and four indicating a negative mood (e.g. sad, miserable). Participants were instructed to rate the extent to which they feel each adjective at the moment on a scale ranging from '1' (not at all) to '7' (very much). We averaged the ratings of the participants for all negative adjectives into a negative index, and the rating for the positive adjectives into a positive mood index.

**Interpersonal perception assessment.** The IPT was developed by Costanzo and Archer, (1989) as a standardized method of assessing the accuracy of social judgments in interpersonal situations. It requires participants to perceive accurately non-verbal aspects of social communication (e.g. personal space, facial expressions, tone of voice, etc.) within a verbal dialogue (Fischer-Shofty et al., 2013).

The task consists of brief naturalistic scenes of interacting people. Before each film, participants are presented with a question asking them to draw a conclusion regarding the relationship between the interacting people in the next scene. Participants are provided with an answering sheet containing the questions and two or three possible answers for each one. The scenes are followed by a six seconds blank interval during which participants are asked to choose and write their answer on the answering sheet. In the current study, four types of common social interactions were selected: kinship, intimacy, competition and deception. In the kinship condition, participants were asked which of the interacting people are family relatives. In the intimacy condition, they were asked to identify the type of relationship that the interacting individuals have (e.g. are they strangers, friends, romantic partners, etc.). In the competition condition, participants were asked which of two interacting individuals won a competition. Finally, in the deception condition, participants were instructed to identify which of the individuals is lying and which is telling the truth. Four scenes were selected for each of the task conditions, and these were further assigned randomly into two versions, thus making a total of eight scenes for each task version. The participants' accuracy rate was calculated for each condition of the task by the sum of correct answers participants had made at each category.

**Experimental procedure.** We used a double-blind, within-subject design. Each participant underwent two experimental sessions within a one-week interval. Participants were introduced to the experiment by a female experimenter who was using hormonal contraceptives at the time of the experiment. This was in order to avoid any contamination of the study's findings resulting from menstrual cycle changes in her body odor and behavior (Kuukasjärvi et al., 2004; Miller et al., 2007). During the session, participants were exposed to one of the two compounds, either to EST or to the control solution. Compounds were presented continuously throughout the session using a pre-prepared Band-Aid containing 100  $\mu$ l of solution that was placed above the participants' upper lip (as suggested by Frumin and Sobel, 2013). Solutions were completely soaked within the Band-Aids, having no contact with participants' skin. Following the placement of the Band-Aid, participants were instructed to begin the IPT. The order of compound presentation was counterbalanced.

## Experiment II

**Participants.** A priori sample size estimates indicated for a power of 0.80, a minimum of 66 participants to detect a small-medium effect size stems from the hypothesized intersection ( $\eta_p^2 = 0.03$ ); therefore, we aimed to recruit this amount of participants. To this end, sixty-four men ranging in age from 22 to 35 (mean 26.89, SD = 3.21) were recruited via advertisements posted in the social media and at the University of Haifa. All completed an online screening questionnaire aimed to test their suitability for the current experiment. They were required to meet the same inclusion criteria as described for the first experiment. The experiment was approved by the University of Haifa's Ethics Committee. All participants signed an informed consent and were given credit or payment for their time.

**Experimental task.** The task was programmed using the E-prime 2.0 software package (Schneider et al., 2002). This task was adapted from the study of Peled-Avron et al. (2016). Participants were presented with 64 black-and-white images in a randomized order. In each trial, participants were shown one image that depicted either two humans or two inanimate objects that were either touching or were in a close proximity but not touching. Images of humans did not show their faces in order for participants to focus on touch and not on facial expressions. For the creation of the stimuli, romantic partners were asked to take a spontaneous picture of themselves together as they romantically touch each other and again in a similar setting and posture but without touching each other. Eight pairs consented to the use of their pictures for this study. Human touch was depicted as hand-holding, a hug or a hand on the shoulder or arm. Inanimate touch was depicted as two everyday touching objects (Figure 1). Participants were asked to rate the degree to which they would like to include this photo in an album with an emotional content. Each experimental condition consisted of 15 trials presenting one image, resulting overall in 60 trials. Each trial began with a 500 ms presentation of a fixation cross followed by an inter-stimulus interval that varied in duration (200, 250 or 300 ms). Upon image display, participants were asked to press the space bar as soon as they knew how they would like to rate the image. Once they pressed the space bar, participants were presented with a visual analog scale that ranged from 'this photo will be excluded from the album' to 'this photo will be included in the album'. They were instructed to rate the likelihood that they would include the picture in an emotional album. Following the participants' reaction, a black screen of a random duration (200, 400 or 600 ms) was presented to reduce the generation of a monotonous task rhythm. Four practice trials were included in order to ensure the participants' understanding of the instructions. Both the presentation and instructions were similar to those given in the study by Peled-Avron et al. (2016).

**Task validation.** In order to confirm that the touch perception task used in the second experiment does not measure merely elements that are associated with general social cognition, we conducted a preliminary study with 38 participants using the Interpersonal Reactivity Index (IRI) questionnaire (Davis, 1983). This questionnaire was translated to Hebrew and validated by Even (1993) (unpublished data). The IRI is a self-report measure consisting of four subscales assessing the emotional and cognitive reactivity to others. We confirmed that the overall emotionality rating given for the touch images included in the task positively correlated with participants' reported empathic concern ( $r_p = 0.33$ ,  $P = 0.04$ ). The latter is a scale that measures

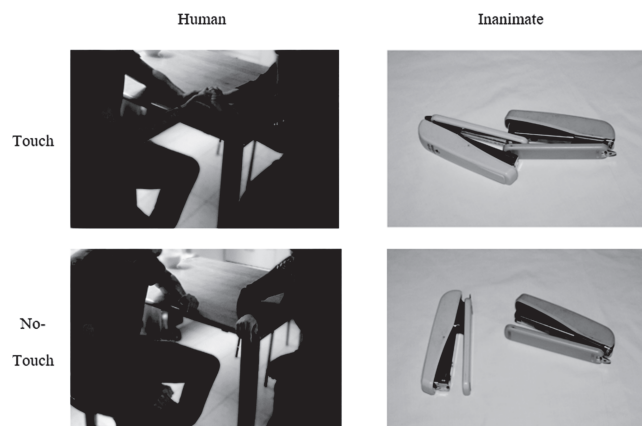


Fig. 1. Presented images. A total of 60 images were presented to the participants. Images consisted of four categories presented to the participants; two touching humans, two touching inanimate objects, two non-touching humans and two non-touching inanimate objects.

feelings of sympathy and concern for unfortunate others. We concluded that the touch perception task is associated with a known measure of emotional empathy (i.e. empathic concern), thus specifically relates to empathy and not merely to general social cognition.

**Experimental procedure.** Compound preparation and presentation was the same as described in Experiment 1. We used a double-blind, within-subject design. Each participant underwent two experimental sessions within a one-week interval. In each session, they were exposed to one of the two compounds continuously throughout the entire session. During each session, the participants performed the picture-rating task. The order of compound presentation was counterbalanced.

## Results

### Experiment 1

A two-way repeated-measures analysis of variance (ANOVA) was performed with compound (EST or control solutions) and mood valence (positive and negative) as within-subject factors.

There was no significant overall effect for compound on the mood ratings [ $F_{(1,55)} = 0.695$ ,  $P = 0.408$ ,  $\eta_p^2 = 0.012$ ] or an interaction with the mood valence [ $F_{(1,55)} = 0.420$ ,  $P = 0.520$ ,  $\eta_p^2 = 0.008$ ]. There was a general valence effect [ $F_{(1,55)} = 365.378$ ,  $P = 0.000$ ,  $\eta_p^2 = 0.869$ ] demonstrating that participants indicated they were in a general positive mood ( $M = 4.899$ ,  $SD = 0.963$ ) rather than in a negative mood ( $M = 2.031$ ,  $SD = 0.824$ ).

We conducted a two-way repeated-measures ANOVA, with compound (EST or control solutions) and task category (i.e. kinship, intimacy, competition and deception) as within-subject factors. The dependent variable was the accuracy level as indicated by the number of correct answers made by the participants.

The overall main effect for compound was significant [ $F_{(1,55)} = 5.35$ ,  $P = 0.024$ ,  $\eta_p^2 = 0.089$ , 95% CI (0.014, 0.200)], indicating a higher accuracy level under exposure to EST ( $M = 1.036$ ,  $SD = 0.359$ ) rather than under exposure to the control solution ( $M = 0.929$ ,  $SD = 0.0269$ ). The main effect for the task category was significant as well [ $F_{(3,165)} = 11.74$ ,  $P = 0.000$ ,  $\eta_p^2 = 0.176$ ]. Further pairwise comparisons using Bonferroni-correction indicated that the accuracy levels for the intimacy category were significantly lower than those for kinship and for competition. Accuracy levels for the competition category were higher than

those for deception ( $P < 0.05$ ). For the interaction between compound and the task category, Mauchly's test of sphericity indicated a violation of the assumption of sphericity (Mauchly's  $W = 0.806$ ,  $P = 0.041$ ). Therefore, a correction was made according to Huynh-Feldt criteria (Epsilon = 0.836). This interaction was not significant [ $F_{(2.81, 154.52)} = 0.97$ ,  $P = 0.402$ ,  $\eta_p^2 = 0.017$ ] (Figure 2).

Paired-sample *t*-tests were employed to identify changes in accuracy levels for four task categories across compounds. Bonferroni-adjusted alpha of 0.0125 per test was used for each comparison. As shown in Table 1, none of the comparisons within each task category reached significance following the correction, although exploration of the effect sizes demonstrated that the effect of EST on accuracy level was significant only in the intimacy category.

### Experiment 2

We conducted a three-way repeated-measures ANOVA, with compound (EST or control solutions), touch (which or without touch) and stimulus type (human or inanimate objects) as within-subject factors. The dependent variable was the inclusion rate in an emotional album, representing the degree to which participants perceived the picture to be emotional.

A significant main effect was found for touch [ $F_{(1,63)} = 236.99$ ,  $P = 0.000$ ,  $\eta_p^2 = 0.79$ , 95% CI (21.83, 28.34)], with a higher inclusion rate for touching ( $M = 54.12$ ,  $SD = 11.89$ ) vs non-touching objects ( $M = 29.04$ ,  $SD = 10.23$ ). We further found a significant main effect for stimulus type [ $F_{(1,63)} = 534.96$ ,  $P = 0.000$ ,  $\eta_p^2 = 0.89$ , 95% CI (42.08, 50.04)], with a higher inclusion rate for human ( $M = 64.61$ ,  $SD = 10.58$ ) vs inanimate objects ( $M = 18.54$ ,  $SD = 13.26$ ). The main effect for compound was not significant [ $F_{(1,63)} = 0.74$ ,  $P = 0.394$ ,  $\eta_p^2 = 0.012$ , 95% CI (-0.965, 2.42)], suggesting that there was no overall effect of EST on the inclusion rate. A significant two-way interaction was found between touch and stimulus type [ $F_{(3,63)} = 55.69$ ,  $P = 0.000$ ,  $\eta_p^2 = 0.47$ ]. We further found a significant two-way interaction between touch and compound [ $F_{(1,63)} = 6.10$ ,  $P = 0.016$ ,  $\eta_p^2 = 0.088$ ]. The interaction between stimulus type and compound was not significant [ $F_{(1,63)} = 0.013$ ,  $P = 0.909$ ,  $\eta_p^2 = 0.000$ ], neither was the three-way interaction between touch, stimulus type and compound [ $F_{(1,63)} = 0.097$ ,  $P = 0.757$ ,  $\eta_p^2 = 0.002$ ].

Follow-up analysis using a two-way repeated-measures ANOVA demonstrated a significant main effect for compound within the trials where objects were touching [ $F_{(1,63)} = 4.105$ ,

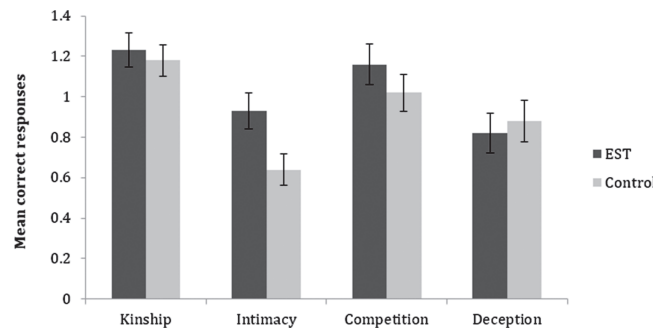


Fig. 2. Comparison of the mean (SEM) number of correct responses obtained under exposure to EST or the control solution with respect to the task category. A significant main effect was found for compound ( $P = 0.024$ ,  $hp^2 = 0.089$ ) with higher accuracy obtained under exposure to EST.  $N = 56$ .

Table 1. Mean (SD) accuracy level for the different task categories and the difference between participants' accuracy under exposure to EST and the control solution

Task category	EST	Control	Statistic	P-value	Cohen's $d_z$
Kinship	1.23 (0.632)	1.18 (0.575)	$t_{(55)} = 0.490$	0.626	0.066
Intimacy	0.93 (0.684)	0.64 (0.586)	$t_{(55)} = 2.211$	0.031	0.296
Competition	1.16 (0.757)	1.02 (0.674)	$t_{(55)} = 1.033$	0.306	0.138
Deception	0.82 (0.741)	0.88 (0.764)	$t_{(55)} = -0.344$	0.732	-0.046

Note. None of the comparisons reached significance using a Bonferroni-adjusted alpha of 0.0125. Observation of effect sizes revealed that the most profound change in accuracy level was at the intimacy category.  $N = 56$

$P = 0.047$ ,  $\eta_p^2 = 0.061$ , 95% CI (0.03, 4.16)], with a higher inclusion rate given under exposure to EST ( $M = 55.16$ ,  $SD = 11.4$ ) than under exposure to the control solution ( $M = 53.07$ ,  $SD = 13.67$ ). A significant main effect was also found for stimulus type [ $F_{(1,63)} = 456.50$ ,  $P = 0.000$ ,  $\eta_p^2 = 0.88$ , 95% CI (50.03, 60.36)], with a higher inclusion rate for humans ( $M = 81.71$ ,  $SD = 11.43$ ) vs inanimate objects ( $M = 26.52$ ,  $SD = 19.12$ ). The interaction between compound and stimulus type was not significant [ $F_{(1,63)} = 0.056$ ,  $P = 0.814$ ,  $\eta_p^2 = 0.001$ ].

Within the trials where objects were not touching, the main effect for compound was not significant [ $F_{(1,63)} = 0.419$ ,  $P = 0.520$ ,  $\eta_p^2 = 0.007$ , 95% CI (-2.62, 1.34)]. The main effect for stimulus type was significant [ $F_{(1,63)} = 320.72$ ,  $P = 0.000$ ,  $\eta_p^2 = 0.84$ , 95% CI (32.81, 41.05)] with a higher emotionality rating allocated for human ( $M = 47.50$ ,  $SD = 15.72$ ) vs inanimate objects ( $M = 10.57$ ,  $SD = 9.928$ ). However, the two-way interaction between compound and stimulus type was not significant [ $F_{(1,63)} = 0.003$ ,  $P = 0.954$ ,  $\eta_p^2 = 0.000$ ] (Figure 3).

## Discussion

In this study, we investigated the effect of exposure to the chemosignal estratetraenol on men's social cognition. In the first experiment, we presented participants with a social cognition task that they performed twice, once under exposure to EST and once under exposure to a control solution. We found an overall improvement in social cognition but the most profound improvement was in the intimacy category, where participants identify the nature of the relationship between interacting individuals (e.g. How long are they in a relationship? Are they siblings or sexual partners?). In the second experiment, we explored men's emotional reaction to observed romantic touch. We did not assess directly the perceived emotionality of touch, rather we used a more naturally implicit measure where participants rated the likelihood of including photos in an emotional album. In line with our hypothesis, we found that exposure to EST

increased the participants' inclusion rate of photos depicting touch in an emotional album. Interestingly, participants did not discriminate between romantically touching humans and touching inanimate objects, as the perceived emotionality of both types of stimuli increased under exposure to EST. Neither of the results could be attributed to changes in the participants' mood during the different sessions of the experiment, as it remained relatively positive across both sessions, and did not change as a result of exposure to EST.

In accordance with former studies indicating that EST influences perception and behavior in the context of mating and sexuality (Monti-Bloch and Grosser, 1991; Bensafi et al., 2004; Cornwell et al., 2004; Zhou et al., 2014), the results of the current study support the notion that EST acts as a chemosignal. This is because EST may convey mating-relevant information such as the presence of women and/or their reproductive readiness, similarly to pheromones' role in the animal kingdom. In non-human mammals, female body odors are known to stimulate the male reproductive system (Brown and Macdonald, 1985) and increase sexual arousal and behavior (Ziegler et al., 1993). In humans, women's body odor changes throughout the menstrual cycle so that it is perceived as more attractive by men during ovulation (Kuukasjärvi et al., 2004; Roberts et al., 2004; Havlíček et al., 2006). Furthermore, exposure to women's body odor from ovulation leads to an elevation in testosterone levels (Miller and Maner, 2010) and a further change in several mating-related behaviors including risk-taking (Miller and Maner, 2011) and approach behavior (Oren and Shamay-Tsoory, 2017). These behavioral changes are suggested to result from an increase in men's mating motivation at the time of the exposure (Miller and Maner, 2011). The results of the current study may also stem from a similar increase in mating motivation that may affect men's behavior in various ways, such as their social cognition abilities (Ickes et al., 1990), especially in interactions that imply a sexual context. Thus, it is possible that women's secretions during ovulation contain higher concentrations of EST, which in turn

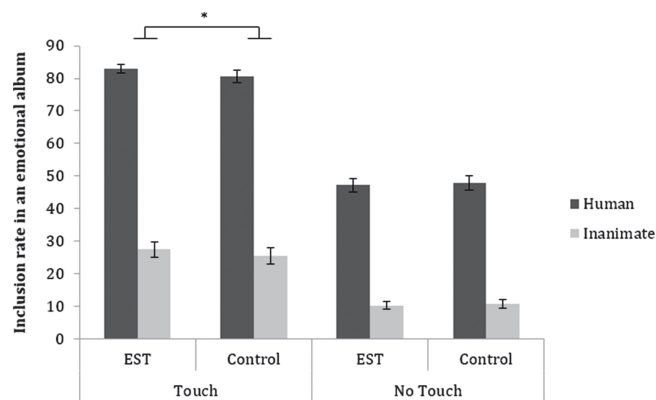


Fig. 3. Comparison of the mean (SEM) emotionality ratings obtained under exposure to EST or the control solution with respect to touch condition. A significant main effect was found for compound in trials where pictures depicted touch ( $P = 0.047$ ,  $\eta_p^2 = 0.061$ ) with higher emotionality ratings obtained under exposure to EST.  $N = 64$ .

enable men to detect changes in women's fertility status using their chemosignaling sensing. Further studies investigating this hypothesis are necessary.

Collectively, we further suggest that the results of the current study can be explained by an increase in men's social cognition following exposure to EST. As exposure to EST increased social cognition abilities particularly at intimate encounters, and increased perceived emotionality of romantic touch, we propose that EST may in fact affect sexual cognition. This is a new term that may be used in future studies to describe the elements of social cognition that allow for sexual behavior and/or interactions. Sexual cognition may be conceptualized as a sub-element of social cognition that enables humans to recognize and act according to cues in the environment that suggests sexual opportunities. Such cognitive abilities are crucial for inferring cues regarding the nature and closeness of human relationships in a process that may involve identification and simulation. Here, we suggest that exposure to EST increases the salience of sexual cues in the social environment. Accurate sexual perception is imperative for an appropriate social functioning in a group. Evolutionary research claims that high-level social skills are crucial for reproductive success (Hartung, 1988). In the current study, while men were exposed to EST, they demonstrated increased interpersonal sensitivity (Bernieri, 2001), and their ability to make correct social inferences based on social cues was significantly increased (e.g. other's facial expressions, tone of voice, body posture and movement) (Hall et al., 2009). Several elements in the process of social perception may be used differently under diverse mental states and according to various motivations (Niedenthal and Halberstadt, 2003). Moreover, mating motivation was found to be one of the mental states that influence the amount of effort invested in understanding the opposite sex individual's thoughts and feelings (Ickes et al., 1990). Thus, the results of the current study may be explained by an increase in mating motivation in male subjects as a result of exposure to the chemosignal EST. Such increased mating motivation may in turn elevate the amount of effort invested in understanding the social environment, especially when the environment contains mating-related information. Higher social sensitivity of men to subtle social and sexual cues may promote their understanding of a woman's state of mind and her intentions (for example, is that woman interested?) and their relationships with others (for example, is that woman single? Or is that her spouse?). A deeper understanding of such social cues may improve men's chances of successful mating. This

notion is in line with our finding that the most profound change in the assessment of social situations was in the category of intimacy, where participants identify the nature of a relationship between two characters. This finding is consistent with the above claim that a better understanding of the surrounding sexual relationships is important for a productive investment of mating efforts. Future studies exploring these suggestions directly are warranted.

Our results from the second experiment demonstrate that exposure to EST increases the perceived emotionality of both romantically touching humans and touching inanimate objects, possibly through increasing identification with the touching objects. As touch serves as a key means for communication of thoughts and feelings (Hertenstein et al., 2006), the finding that EST increases perceived emotionality of romantically touching humans supports the notion that EST enhances men's sexual cognition abilities, as they accurately perceive and identify with the emotions that elicit the touch. We hypothesized that EST would affect merely the perceived emotionality of touching humans; however, we found an overall effect at which EST affected the perception of both human and non-human touch. This is a finding that is supported by the results of Ebisch et al. (2008). Using functional magnetic resonance imaging, the authors confirmed previous studies demonstrating shared neural circuits, including the secondary somatosensory cortex, for both experienced and observed touch. They further extended these findings by showing that the same neural network that creates the representation of experienced and observed human touch is active during observation of touching inanimate objects. Thus, as the neural network representing human touch shares the same regions of that representing non-human touch, it is possible that exposure to a chemosignal that presumably affects this neural network would influence perception of both stimuli types.

Another possible interpretation is that exposure to EST enhanced the participants' tendency to anthropomorphize touching inanimate objects. Anthropomorphism is the human tendency to attribute non-human agents with human-like characteristics such as intentions, emotions and motivation (Epley et al., 2007). Using a similar paradigm to that of the current study, Peled-Avron et al. (2016) found a significant correlation between participants' rating of the humanity of touching inanimate objects (i.e. the level of anthropomorphism) and their emotionality ratings. Therefore, it is possible to assume that exposure to EST influences the degree of humanity

attributed to inanimate objects, and that may account for the reason that the present study's participants rated touching inanimate objects as more emotional. The literature in the field of anthropomorphism suggests that the human tendency to anthropomorphize inanimate objects can be predicted by their motivation to act as efficient social agents in the moment (Epley et al., 2007). As adequate social functioning is a key component of reproductive success (Hartung, 1988), mating possibilities could motivate men to act efficiently in the social environment. As has previously been suggested, such a motivation may increase man's ability to accurately identify subtle social cues in the environment, resulting in an 'over-identification' of such cues in objects as well. A possible implication of these findings is in understanding mechanisms of fetishism, a tendency of a person to experience sexual attraction towards inanimate objects (Barlow and Durand, 2012).

In conclusion, our findings demonstrate that the chemosignal EST affects sexually and romantically related elements of social cognition. EST may convey information regarding women's readiness for reproduction, thus increasing men's mating motivation and salience to environmental cues pertaining to mating behavior. This motivation encourages men to identify with emotional stimuli and better understand interpersonal interactions. Our findings highlight the importance of EST in human chemosignaling in the social environment.

## Declaration of Interests

The authors declare no competing interests.

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