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Androstadienone, a putative chemosignal of dominance, increases gaze avoidance among men with high social anxiety

A. Banner[a,*], S. Gabay[a,b], S. Shamay-Tsoory[a]

[a] Department of Psychology, University of Haifa, Abba Khoushy Ave 199, Haifa, Israel
[b] The Institute of Information Processing and Decision Making, University of Haifa, Abba Khoushy Ave 199, Haifa, Israel

ABSTRACT

Socially anxious individuals show increased sensitivity toward social threat signals, including cues of dominance. This sensitivity may account for the hypervigilance and gaze avoidance commonly reported in individuals with social anxiety. This study examines visual scanning behavior in response to androstadienone (androsta-4,16,-dien-3-one), a putative chemosignal of dominance. We tested whether exposure to androstadienone would increase hypervigilance and gaze avoidance among individuals with high social anxiety. In a double-blind, placebo-controlled, within-subject design, 26 participants with high social anxiety and 26 with low social anxiety were exposed to androstadienone and a control solution on two separate days. On each day, an eye-tracker recorded their spontaneous scanning behavior while they viewed facial images of men depicting dominant and neutral poses. The results indicate that among participants with high social anxiety, androstadienone increased gaze avoidance by reducing the percentage of fixations made to the eye-region and the total amount of time spent gazing at the eye-region of the faces. Participants with low social anxiety did not show this effect. These findings indicate that androstadienone serves as a threatening chemosignal of dominance, further supporting the link between hypersensitivity toward social threat cues and the perpetuation of social anxiety.

1. Introduction

In order to efficiently navigate the social world, humans possess a crucial ability to interpret social dominance cues (Chiao, 2010). Nonetheless, some individuals are more attuned to cues of dominance than others. Studies have shown that individuals with social anxiety show increased sensitivity to dominance signals as compared to individuals without social anxiety (Maner et al., 2008b; Aderka et al., 2013; Haker et al., 2014; Banner and Shamay-Tsoory, 2018b). Socially anxious individuals are preoccupied with the impression they make and place fundamental importance on being positively appraised by others. As a result, they perceive a variety of everyday social situations as threatening, often respond to social situations with exaggerated distress and tend to avoid these situations (Hofmann, 2007). Explanatory theories of social anxiety suggest that this condition may reflect concerns about one's place in the social hierarchy and may lead to maladaptive submissive behavior (Trower and Gilbert, 1989; Gilbert and Trower, 2001). According to these theories, socially anxious individuals tend to view the world from a hierarchical perspective: They see themselves as being low on the hierarchical social ranking and others as dominant competitors for social status. As a result, they feel incompetent to achieve social status, and instead focus on avoiding harm and conflict with dominant others. This tendency may result in adopting submissive and avoidant behaviors (Walters and Hope, 1998).

A commonly reported symptom of social anxiety is the avoidance of eye contact during social interactions with others. Research has suggested that socially anxious individuals respond with gaze avoidance in an attempt to prevent feared social catastrophes (e.g., Clark and Wells, 1995) or as submissive behavior (Mazur and Booth, 1998; Horley et al., 2004). In support of this suggestion, self-reported fear and avoidance of eye contact were found to correlate with overall severity of social anxiety and shown to decrease with successful treatment (Schneier et al., 2011). Other studies revealed that socially anxious individuals made less eye contact during both benign (Baker and Edelmann, 2002) and conflict-primed social interactions (Langer et al., 2017). A growing body of research using eye-tracking technology has facilitated a deeper examination of this phenomenon. While healthy individuals tend to show a triangular pattern of visual scanpaths in which fixations are directed to the mouth and eyes (e.g.,Walker-Smith et al., 1977; Mertens et al., 1993), socially anxious individuals tend to show fewer fixations and spend less time dwelling on the eye region of presented facial images (Horley et al., 2003, 2004; Moukheiber et al., 2010, 2012) and

of actors in video clips (Weeks et al., 2013). Moreover, in addition to the marked avoidance of the eyes, socially anxious individuals demonstrate hypervigilance (i.e., enhanced attention), characterized by a higher proportion of initial gaze towards emotional faces (Garner et al., 2006; Wieser et al., 2009) and a longer scanpath length (hyperscanning) (Horley et al., 2003, 2004; Chen et al., 2015). According to the "vigilance-avoidance" model (Mogg et al., 1997), hypervigilance and gaze avoidance can be respectively construed as initial vigilance for threat and the subsequent defensive strategy used to alleviate anxiety.

Although sensitivity to visual cues of dominance and threat in social anxiety has been thoroughly investigated, the research on sensitivity to chemical cues of social dominance and threat among those with social anxiety is still in its infancy. Adolph et al. (2010) revealed the first evidence of hypersensitivity to chemical signals of dominance in social anxiety. They reported that high levels of social anxiety were associated with greater skin-conductance response to chemosignals of victory (axillary sweat upon winning sports competitions). Since dominance and victory are associated with increased levels of testosterone (Booth et al., 1989; Mazur and Booth, 1998), it is plausible that testosterone metabolites are secreted in such states via the apocrine glands, which are known to be active in various emotional situations (Wilke et al., 2007). Androstadienone (androsta-4,16,-dien-3-one; AND) is a testosterone metabolite (Stylianou et al., 1961; Rennie et al., 1989) found in human axillary sweat (Labows, 1988), that has been suggested to act as a human chemosignal (Grosser et al., 2000; Jacob et al., 2001b). Researchers have shown AND to drive various behavioral effects, some of which suggest that AND acts as a chemical signal of dominance or social threat (Frey et al., 2012; Zhou et al., 2014; Hornung et al., 2017; Banner et al., 2018; Banner and Shamay-Tsoory, 2018b). For example, Frey et al. (2012) reported that AND enhanced the motor response to social threat signals, suggesting that exposure to AND in a potentially dangerous situation may enhance attention toward a threatening social stimulus. Furthermore, Zhou et al. (2014) reported that exposure to AND biased homosexual men and heterosexual women to perceive digitized human motion as more masculine, an attribute closely related to dominance. Moreover, men who were exposed to AND showed reduced interference in the visual processing of threatening facial expressions, suggesting that AND prepares men for a potential conflict (Hornung et al., 2017). Additionally, Banner et al. (2018a) showed that AND increases individualistic withdrawal behavior during competitive interaction with other men, suggesting an avoidance/submissive response to a chemosignal of dominance. Recently we reported specific hypersensitivity to AND among individuals with high social anxiety (HSA): Male faces were rated by HSA individuals as being more dominant when they were under exposure to AND than when they were under exposure a control solution (Banner and Shamay-Tsoory, 2018b). It should be noted that socially anxious individuals were shown to have increased sensitivity toward other threat-related chemosignals (Pause et al., 2009, 2010; Adolph et al., 2013), suggesting broader hypersensitivity to social chemosignals in social anxiety.

Building on these findings, the current study sought to examine the effect of the chemosignal AND in conveying dominance and inducing a submissive-avoidance response from HSA participants. We hypothesized that in individuals with high social anxiety (but not in those with low social anxiety), exposure to AND as a threatening chemosignal of dominance would result in increased vigilance and gaze avoidance while viewing images of men in dominant and neutral poses. We further predicted that this effect would be stronger in reaction to images depicting congruent-dominant facial poses, compared to neutral facial poses.

2. Method and materials

2.1. Participants

Fifty-two male participants were recruited (via advertisements at

the University of Haifa and on the internet) following a screening procedure that included 195 participants who completed the Mini-SPIN (see below). The final sample included men ranging in age from 18 to 39 years (mean: 25.58, S.D: 4.3). All had 12–16 years of education, and all were fluent Hebrew speakers. This study was part of a larger study in which we examined the effect of AND on dominance perception. (The behavioral ratings of pictures of part of this sample are reported in Banner and Shamay-Tsoory, 2018b.) The participants reported that they were in general good health, non-smokers, heterosexual, not taking chronic or acute medication and not suffering from any somatic or mental illness or from known olfactory problems. Additionally, all participants had normal or corrected-to-normal vision. Participants were classified as either high on social anxiety (HSA) or low on social anxiety (LSA) based on their score on the Mini-Social Phobia Inventory (Mini-SPIN). The Mini-SPIN is a validated and reliable self-report questionnaire for screening social anxiety disorder in adults, with a cutoff score of 6 yielding strong sensitivity and diagnostic efficiency (Connor et al., 2001). Therefore, a Mini-Spin score of six or more was required for a participant to be classified as HSA. Since more individuals with low levels of social anxiety (Mini-Spin < 6) responded to our advertisements than those with high levels of social anxiety, we invited all HSA responders to take part in the experiment and randomly invited an equal number of participants from the LSA group to participate. Following this screening process, each social anxiety group (HSA/LSA) contained 26 participants. To confirm a significant difference in levels of social anxiety between the two groups, all participants also completed the Liebowitz Social Anxiety Scale (LSAS) (Liebowitz, 1987). The HSA group scored well above the suggested cut-off score of 30 (Mennin et al., 2002) for Social Anxiety Disorder (M = 53.20, SD = 23.47), while the LSA group scored within the normal range (M = 26.50, SD = 13.8; group comparison: p < 0.001). The two groups did not differ in age (LSA mean = 25.04, SD = 4.01; HSA mean = 26.12, SD = 4.6, group comparison: p = 0.37). Participants gave written informed consent and were paid or given credit points for their participation. The Ethics Committee of the University of Haifa approved the study.

2.2. Olfactory stimuli

Based on previous studies (e.g., Jacob et al., 2001a; Hummer and McClintock, 2009; Banner et al., 2018a), the experimental stimulus contained 250 μM of AND (Steraloid, Inc.) diluted in propylene glycol (sigma Aldrich; purity 99%). In order to eliminate the effects of perceived odor of AND, we used an odor mask of 1% eugenol (sigma Aldrich; purity 99%). The control solution contained propylene glycol along with the same odor mask of 1% eugenol. To allow for continued exposure throughout the experiment, participants were exposed to both solutions via a Band-Aid containing 100 μl of the selected solution, pasted above their upper lip and under their nose (Frumin and Sobel, 2013).

2.3. Visual stimuli

All visual stimuli were adapted from Rule et al. (2012). The facial stimuli included images of five Caucasian men, each displaying one dominant and one neutral pose (a total of 10 different images). Based on previous studies (Chiao et al., 2008; Mignault and Chaudhuri, 2003), a dominant pose was conveyed by a direct eye gaze and an upward head tilt, whereas a neutral pose was expressed by a direct eye gaze with no head tilt. None of the male targets had facial hair or wore any facial adornments, such as jewelry and glasses. The photographs were standardizing to be roughly equal in size and converted to grayscale.

2.4. Experimental task and apparatus

Participants were seated in a reclining chair in front of a computer,

in a well-ventilated, temperature-controlled test room. Eye movements and foveal fixation were monitored with an EyeLink 1000 eye tracker (SR Research, Ottawa, ON, Canada). A head restraint minimized head movements and ensured a 64 cm distance between the participant and the computer screen. After a standard calibration procedure, participants were instructed that they would be seeing several images and that they can look at these images in any manner they wish until they disappear. Presentation of each image was initiated only after the participant maintained fixation on the fixation cross for 1 s and pressed the space bar. One image at a time was shown at the middle of the screen in such a way that the fixation cross was situated on the nasal bridge below the eyes of the protagonist. Images were repeated twice, resulting in a total of 20 randomized images. Each image was presented for 8 s, followed by an interstimulus interval (blank screen) of 7–9 seconds. Six individuals did not successfully pass the calibration test and were thus unable to participate in the study.

2.5. Procedure

We used a double blind, placebo-controlled, within-subjects design. Participants were exposed to androstadienone and the control solution in two separate sessions (counterbalanced for order) that were held at the same time of day, within 7 days of each other (mean = 2.44 days apart, SD = 1.98). In order to assess individual discrimination ability of AND, we administered a 3-alternative forced choice test at the beginning of the first session, prior to the experimental task. The test consisted of a flask containing 250 μM solution of AND solved in 1% Eugenol and propylene glycol and two other identical flasks containing 1% Eugenol solved in propylene glycol. Each participant was requested to indicate the flask that was different from the other two. The participant's response was noted, without feedback. Then, a Band-Aid containing the solution was applied under the participants' noses, and each participant was asked to rate the odor of the solution on a scale of 1–9 for pleasantness, familiarity and intensity. This rating was repeated again in the second session. After that, participants completed the eye-tracking task. Both sessions for each participant were run by the same female experimenter (four experimenters in total, all taking oral contraceptives to reduce hormonal fluctuations that might otherwise have an influence on participants' performance).

2.6. Data acquisition and analyses

Rectangular areas of interest (AOIs) were created around each eye for each image separately, excluding the inter-ocular space. Noticeably, this procedure resulted in consistently larger AOI's for neutral poses compared to dominant poses. Gaze avoidance was calculated by two parameters: percentage of eye fixations (100 times the number of fixations in the eye-region divided by the total number of fixations) and percentage of eye contact duration (100 times the dwell time in the eye-region divided by the total duration of image presentation). Hypervigilance was also measured by two parameters: hyperscanning - the mean raw scanpath length (total distance, in millimeters, of the saccadic movement made in each trial), and the proportion of initial fixation in the eye-region (100 times the number of trials where the first fixation was made in the eye-region divided by the total number of trials). A fixation was defined as a set of consecutive gaze points, within a diameter of 1° visual angle, for a minimum duration of 100 ms, excluding the initial gaze points on the fixation cross.

Two-way mixed repeated-measures ANOVAs were conducted, with the abovementioned parameters as the dependent variables, posture type (dominant, neutral) and olfactory stimulus (AND/control) as the within-subjects factors, and social anxiety levels (HSA/LSA) as a between-subjects factor.

To make sure that differences in perceived odor qualities did not affect the differences in the dependent variables, paired sampled t-tests were conducted with the odor qualities (pleasantness, intensity, and

familiarity levels) as the dependent variables and the olfactory stimulus (AND/control) as the within-subject factor.

3. Results

3.1. Subjective ratings of solutions

Androstadienone and the control solutions did not differ in their perceived familiarity [Familiarity-control M = 5.44, SD = 2.33; Familiarity-AND M = 5.17, SD = 2.24; t(51) = 0.91, p = 0.37], pleasantness [Pleasantness-control M = 5.46, SD 1.78; Pleasantness-AND M = 5.69, SD = 1.69; t(51) = −1.1, p = 0.24], or intensity [Intensity-control M = 5.33, SD = 2.05; Intensity-AND M = 5.23, SD = 1.75; t(51) = 0.36, p = 0.72], indicating that behavioral differences did not stem from perceived odor qualities.

We found no significant three-way interaction between the subjective ratings, solution type, and social anxiety levels [F(2,49) = 0.31, p = 0.73, partial eta squared = 0.006]. We also did not find any significant differences in the subjective ratings of the solutions within the LSA group [Familiarity diff. t(25) = −0.3, p = 0.76; Pleasantness diff. t (25) = −1.22, p = 0.23; Intensity diff. t(25) = −0.17, p = 0.86] or the HSA group [Familiarity diff. t(25) = 1.45, p = 0.16; Pleasantness diff. t (25) = −0.41 p = 0.68; Intensity diff. t(25) = 0.86, p = 0.39].

3.2. Discrimination test

Twenty-four participants correctly identified AND in the 3-alternative forced choice test. This ratio did not significantly differ from chance level (33.3%), based on a one-sample *t*-test]t(51) = 1.84, p = 0.071[. We also did not find a significant difference between the social anxiety groups (HSA/LSA) in the proportion of participants discriminating AND [Chi-Square = 0.308, p = 0.58].

3.3. Gaze avoidance- percentage of fixations to eyes

Our analysis of percentage of fixations to eyes indicated a main effect for posture type [F(1,50) = 74.72, p < 0.0001, partial eta squared = 0.6]. Pairwise comparisons using Bonferroni correction indicated that the mean percentage of fixations to the eye region of dominant postures (M = 19.54%, SE = 1.67) was significantly lower [p < 0.001] than the mean percentage of fixations to the eye region of neutral postures (M = 26.93%, SE = 1.78). No two-way or three-way interactions with posture type were found.

We found no main effect for olfactory stimulus, such that AND did not significantly change the mean percentage of fixations to eyes (M = 22.75%, SE = 1.96) compared to control solution (M = 23.73%, SE = 7.71) [F(1,50) = 4.24, p = 0.52, partial eta squared = 0.008]. However, we did find a significant interaction between olfactory stimulus and social anxiety level [F(1,50) = 6.83, p = 0.012, partial eta squared = 0.12]. To examine the source of this interaction, we conducted two follow-up within-subjects tests, one for each social anxiety group (LSA/HSA). The analysis for the HSA group indicated a significant main effect for olfactory stimulus, where AND significantly reduced the mean percentage of fixations to the eye region (M = 19.75%, SE = 2.72) compared to control solution (M = 24.71%, SE = 2.77) [F(1,25) = 8.05, p = 0.009, partial eta squared = 0.24]. In contrast, in the LSA group AND did not significantly change the mean percentage of fixations to the eye region (M = 25.73%, SE = 2.82) compared to control solution (M = 22.76%, SE = 2.01) [F (1,25) = 1.44, p = 0.24, partial eta squared = 0.054]. See Fig. 1. We conducted a Pearson correlation analysis between the differential effect (delta) of AND on the mean percentage of fixations to eyes and the participants' Mini-SPIN scores. Our analysis indicated a significant negative correlation, such that higher levels of social anxiety were associated with lower percentage of fixations to eyes under AND compared to control solution [r = −0.37, p = 0.007]. We did not find a similar
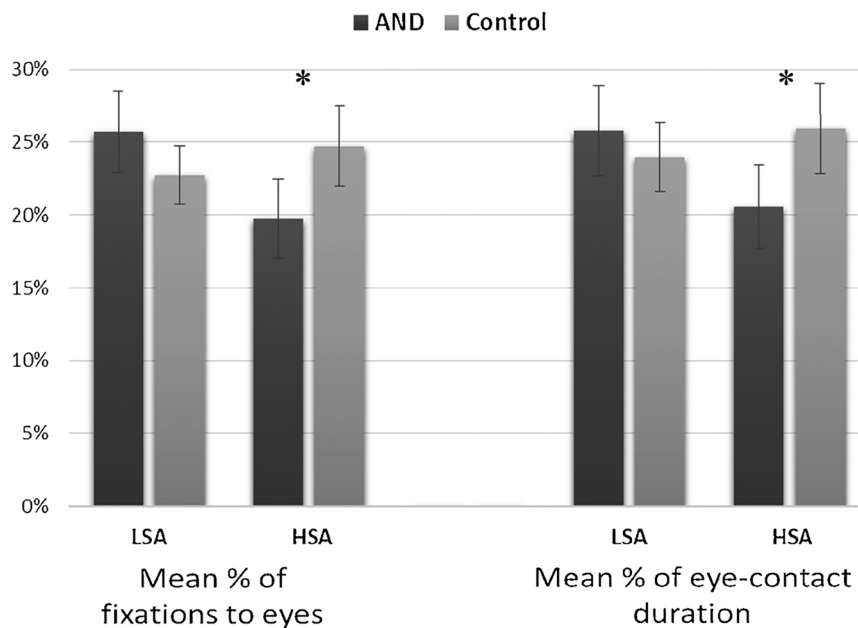
Fig. 1. HSA participants had fewer relative fixations to the eyes and shorter relative eye-contact duration during exposure to AND, compared to control solution. * indicates significant difference (p < .05).
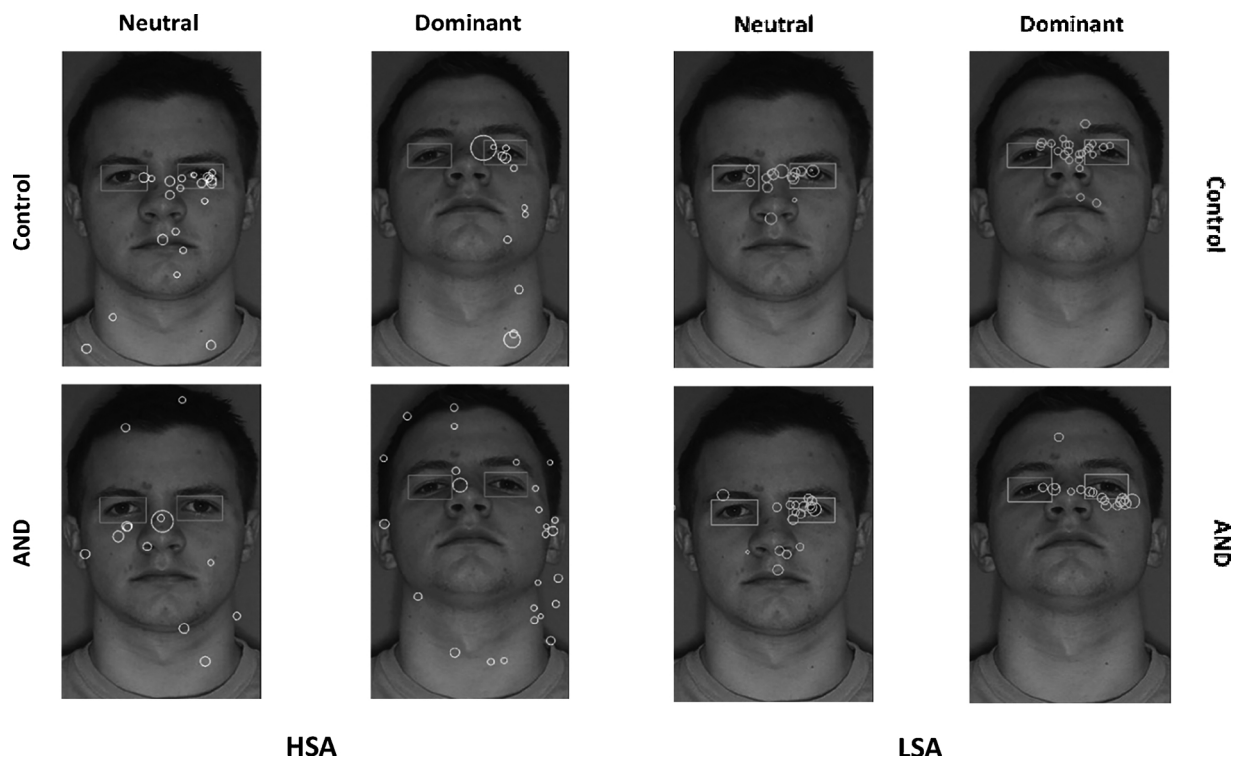

Fig. 2. Examples of scanpaths for neutral and dominant faces in a HSA participant (left) and LSA participant (right), under exposure to AND and a control solution. The HSA participant demonstrates the common avoidance tendency evident in most HSA participants during exposure to AND. Each circle represent a single fixation, while circle size represents the fixation duration (larger circle indicates longer fixation).

correlation within the HSA group alone [r = 0.1, p = 0.61].

The above-mentioned effect could not have been dependent on differences in the total number of fixations made, since we did not find a significant main effect of olfactory stimulus on the total number of fixations [AND (M = 17.75, SE = 0.81), control (M = 18.38, SE = 0.83). F(1,50) = 1.67, p = 0.2, partial eta squared = 0.032]. Moreover, no significant interaction between olfactory stimulus and social anxiety level was observed [F(1,50) = 0.097, p = 0.75, partial

eta squared = 0.002].

3.4. Gaze avoidance- eye contact duration

Our main analysis of eye contact duration also indicated a main effect for posture type [F(1,50) = 63.41, p < 0.0001, partial eta squared = 0.56]. Pairwise comparisons using Bonferroni correction indicated that the mean percentage of eye contact duration for

dominant postures (M = 20.04%, SE = 1.8) was significantly lower [p < 0.001] than the mean percentage of eye contact duration for neutral postures (M = 28.07%, SE = 2.03). No two-way or three-way interaction with posture type was found.

We did not find a significant main effect for olfactory stimulus, indicating that AND did not change the mean percentage of eye contact duration (M = 23.17%, SE = 2.1) compared to control solution (M = 24.94%, SE = 1.95) [F(1,50) = 1.13, p = 0.29, partial eta squared = 0.022]. Nevertheless, we found a significant interaction between olfactory stimulus and social anxiety level [F(1,50) = 4.77, p = 0.034, partial eta squared = 0.087]. To further examine the source of this interaction, we conducted two follow-up within-subjects tests, one for each social anxiety level (LSA/HSA). These analyses indicated a significant effect for olfactory stimulus for the HSA group, where AND significantly reduced the mean percentage of eye contact duration (M = 20.57%, SE = 2.86) compared to control solution (M = 25.95%, SE = 3.1) [F(1,25) = 7.72, p = 0.01, partial eta squared = 0.236]. In contrast, in the LSA group AND did not significantly change the mean percentage of eye contact duration (M = 25.77%, SE = 3.08) compared to control solution (M = 23.98%, SE = 2.36) [F(1,25) = 0.47, p = 0.49, partial eta squared = 0.019]. See Fig. 1. We also conducted a Pearson correlation analysis between the differential effect (delta) of AND on the mean percentage of eye contact duration and the participants' Mini-SPIN scores. This analysis indicated a significant negative correlation, such that higher levels of social anxiety were associated with lower percentages of eye contact duration under AND, compared to control solution (r = -0.32, p = 0.016). We did not find a similar correlation within the HSA group alone [r = 0.15, p = 0.44] (Fig. 2).

3.5. Initial vigilance - percentage of first fixation to eyes

We found no significant main effect for olfactory stimulus, indicating that AND did not significantly change the percentage of first fixation to eyes (M = 11.11%, SE = 1.98) compared to control solution (M = 9.15%, SE = 1.61) [F(1,50) = 1.28, p = 0.26, partial eta squared = 0.025]. We also did not find a significant interaction between olfactory stimulus and social anxiety level [F(1,50) = 0.07, p = 0.79, partial eta squared = 0.001], or a three-way interaction between olfactory stimulus, posture type and social anxiety level [F(1,50) = 2.09, p = 0.15, partial eta squared = 0.04].

3.6. Hypervigilance (hyper-scanning)- raw scanpath length

We did not find a significant main effect for olfactory stimulus, such that AND did not significantly change the raw scanpath length (M = 691.5 mm, SE = 48.3) compared to control solution (M = 721.3 mm, SE = 40.4) [F(1,50) = 0.76, p = 0.38, partial eta squared = 0.015]. Similarly, we also did not find a significant interaction between olfactory stimulus and social anxiety level [F(1,50) = 2.66, p = 0.11, partial eta squared = 0.051], or a three-way interaction between olfactory stimulus, posture type and social anxiety level [F(1,50) = 0.06, p = 0.81, partial eta squared = 0.001].

3.7. Examining confounding factors

To confirm that the order of olfactory stimulus exposure (AND in first session/control solution in first session) did not have effect on our results, we conducted a within-subject repeated-measures ANOVA using "order of exposure" as an additional independent variable. No main or interaction effect with olfactory stimulus or social anxiety level was found, either for eye contact duration or for the percentage of fixations to eyes, indicating that the above-mentioned effects are not due to a confounding effect of order.

To verify that our results did not stem from individual differences in subjective odor qualities of AND, we conducted a Pearson correlation analysis between the individual ratings of AND's odor and the

differential effect (delta) of AND on the percentage of fixations to eyes and the percentage of eye contact duration. Our analyses did not indicate any significant correlation, demonstrating that pleasantness, familiarity or intensity levels of AND had no effect on our results.

To explore whether the results were affected by ability to discriminate AND we conducted an additional analysis adding "discrimination test" (passed/failed) as an independent variable to the main analyses. We did not find a significant relationship between discrimination ability and any of the dependent variables (raw scanpath length, percentages of eye-contact duration and eye region fixations). We also did not find a three-way interaction with the between-subject factor (social anxiety level), indicating that the ability to consciously detect AND had no effect on our results.

4. Discussion

Gaze avoidance is one of the most common behavioral symptoms of social anxiety and is considered a maladaptive submissive-avoidant response to a perceived social threat (Mazur and Booth, 1998; Horley et al., 2004). Here we show that exposure to androstadienone, a putative human chemosignal, increased the gaze avoidance of participants with high social anxiety. We demonstrated that exposure to androstadienone, compared to a control solution, leads to a reduction both in relative duration of eye contact and in foveal fixations on the eye region of other men. These effects were only evident among participants who are relatively high in social anxiety. These findings indicate that androstadienone is a dominance-conveying chemosignal, while adding to the growing body of evidence suggesting hypersensitivity to social threat cues (including chemical signals) among individuals with social anxiety.

Our findings are in accordance with previous research pointing to the eyes as a social threat signal in facial expressions (Öhman, 1986). Eye contact is a particularly important signal in social interactions involving attempted dominance or potential threat (Emery, 2000). A direct eye gaze is considered an indication of dominance/high social rank both in humans (Ellyson and Dovidio, 1985) and in nonhuman primates (Hinde and Rowell, 1962), while the combination of an upward head orientation and a direct gaze was shown to provide the strongest evidence for social dominance (Chiao et al., 2008). Individuals low in social dominance and specifically those who are socially anxious demonstrate a broad attentional bias toward social threats (Bar-Haim et al., 2007; Hirsch and Clark, 2004), with specific preferential processing of dominance cues (Maner et al., 2008a,b; Adolph et al., 2010; Watkins et al., 2010; Aderka et al., 2013). Furthermore, socially anxious individuals have been suggested to over-utilize the social hierarchy system (Trower and Gilbert, 1989), in which they display submissive behaviors (Hermans and Honk, 2006; Maner et al., 2008a,b; Weisman et al., 2011). Given the above, exposure to a potentially threatening interaction, i.e., viewing another man gazing directly at them, while being exposed to AND, may have imposed a dominance threat upon participants with HSA, triggering a submissive avoidant response. LSA participants, in contrast, are not specially biased toward social dominance signals (either visual or chemical) and thus did not consider the social interaction as threatening or as such that necessitates submission.

Biased perception or hypersensitivity to various non-verbal and non-visual social cues has been shown to be evident among individuals with social anxiety (Gilboa-Schechtman and Shachar-Lavie, 2013). Indeed, social anxiety was also associated with an abnormal response to social chemosignals. Individuals with HSA compared to those with LSA exhibited intensified neural activity (Pause et al., 2010) and a heightened startle reflex (Pause et al., 2009) in response to chemical signals of anxiety (sweat taken from donors after anxiety-provoking situations), and high levels of social anxiety were associated with greater skin-conductance response to chemosignals of competition/victory (Adolph et al., 2010). Together, these studies suggest that socially anxious

individuals may respond with stress to several types social chemosignals, with (Adolph et al., 2013) and even without (Adolph et al., 2010) a threatening context. Recently, Banner and Shamay-Tsoory (2018) showed that AND increased the perceived dominance of men's faces, specifically among participants with high social anxiety. In the current study, AND may have increased the perceived dominance of the male protagonists, thus posing a threat to individuals with HSA and incurring an avoidant response to a stressful social stimuli.

While several studies, including the current one, have demonstrated an attentional bias away from social threats among socially anxious individuals, a large body of research has shown an allegedly contradictory tendency—an attentional bias toward threat (e.g., Mogg et al., 2004; Bar-Haim et al., 2007). The "vigilance-avoidance" model (Mogg et al., 1997) resolves this contradiction: Hypervigilance toward threat is associated with early, automatic processing, while avoidance reflects a later, strategic allocation of attentional processes away from threat, possibly as an attempt to alleviate anxiety. In the current study, we hypothesized that among HSA individuals AND would increase the raw scanpath length and the proportion of the first fixation made in the eye-region as an indication of hypervigilance. While previous eye-tracking studies showed an association between social anxiety and longer scanpath lengths while viewing emotional faces (Horley et al., 2003, 2004; Chen et al., 2015), and a tendency to initially fixate (Wieser et al., 2009) and orient gaze towards (Garner et al., 2006) emotional faces, we did not find a similar modulation effect of AND. Thus, our results only partially support the 'vigilance-avoidance' model. These null results may be explained by considering differences in the severity of the disorder. While individuals with a diagnosed social anxiety disorder may be inclined to be vigilant of the environment and to respond with avoidance/submission, sub-clinical socially anxious individuals like the ones in the current study may use avoidance without hypervigilance as a coping mechanism.

It has been suggested by several studies that AND acts as a dominance-conveying chemosignal. First, AND is a metabolite of testosterone (Stylianou et al., 1961; Rennie et al., 1989), a hormone known to be associated with dominance and aggression (Ehrenkranz et al., 1974; Mazur and Booth, 1998). Second, AND has been shown to signal masculinity (Zhou et al., 2014), convey information about male mate quality (Cornwell et al., 2004; Saxton et al., 2008; Ferdenzi et al., 2016), affect intrasexual selection processes (Parma et al., 2012; Huoviala and Rantala, 2013) and modulate responses to social threats (Frey et al., 2012; Chung et al., 2016; Hornung et al., 2017) – all of the above strongly relate to dominance and status. Yet, the effects of AND on gaze avoidance could alternatively reflect an enhanced saliency of social information in general, and not necessarily a selective effect of dominance. For individuals with social anxiety, many social interactions are perceived as threatening. Therefore, if AND is acting as a social signal that generally makes social information more salient, and perhaps even more "real", then when facing other men, eye contact avoidance among the HSA group would be heightened in response to a perceived social threat. Conversely, it may also be that the effects of AND may vary depending on the context and social cues in the environment. In a threatening social context (like the one imposed on our HSA participants), AND may enhance the saliency of the threat and thus promote a submissive or avoidant response, while in a less stressful environment, AND may simply increase attention to emotional cues in general (Hummer and McClintock, 2009), and to positively valenced information in particular (Hummer et al., 2017).

Some limitations to the current study should be addressed. First, our participants did not undergo a formal psychiatric interview in order to diagnose a social anxiety disorder or to rule out other possible psychopathologies. Instead, we treated the HSA group as subclinical. Consequently, we can only speculate that individuals with SAD will respond similarly to, if not more prominently than, our HSA participants. Second, our participants were all men, raising the question of whether our results apply to HSA women as well. The reasons for our

gender selectivity was to rule out confounding effects of attractiveness and other related inter-sexual behaviors. In addition, it was reasoned that men would be more affected by AND given that it has been suggested that men are more attuned than women to signs of social status (Gutierres et al., 1999; Maner et al., 2008a,b). Thus, we must proclaim that any conclusions from this study can be applied only to men. It is also important to note that the effect sizes found for the interaction between social anxiety level and AND exposure in our study were relatively low, and therefore we recommend that future research use larger sample sizes comprising of clinical populations. An additional recommendation for future studies would be to examine the temporal dynamics of the effects of AND, i.e. whether the effects of AND remain stable throughout an entire experimental task. Regarding the significant main effect found for the posture type, we believe that this effect is most likely confounded by the differences in IAOs sizes. The eye-region in the dominant poses was consistently smaller compared to the eye-region in the neutral poses. Thus, no conclusion could be drawn on the shorter eye contact duration and the lower number of fixations in the dominant poses, compared to the neutral poses. Furthermore, we originally expected a stronger effect of AND on images depicting congruent-dominant facial poses, compared to neutral/ambiguous facial poses, but we did not find such an effect. The lack of a differentiating effect of AND on the two posture types is in line with theoretical accounts (e.g.,Gilbert and Trower, 2001) and research studies (e.g., Winton et al., 1995; Veit et al., 2002; Lange et al., 2012) showing that socially anxious individuals misinterpret various neutral (or even affiliative) social signals as being threatening. Therefore, under exposure to AND (a threat signal by itself), neutral postures were perceived as a dominance threat, just as the dominant postures were. Nevertheless, this in fact only highlights the potency of AND, and shows its ability to induce a submissive/avoidant response to both neutral and emotional-congruent visual stimuli.

To conclude, our study sought to examine the role of the chemosignal AND in inducing submissive avoidant behavior among participants with high and low social anxiety. Exposure to an external threat cue—the molecule AND—along with a hypothesized predisposed alertness to social threat cues among HSA participants resulted in active avoidance (gaze aversion) of threating visual stimuli. LSA participants, on the other hand, are not particularly biased toward (visual or chemical) social dominance signals and thus did not avert their gaze in submission. These findings support the role of androstadienone as a chemosignal of dominance and further support the link between hypersensitivity toward social threat cues and the generation and maintenance of social anxiety.

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