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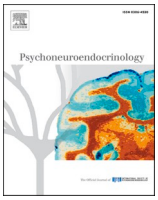

The role of psychopathic traits, social anxiety and cortisol in social approach avoidance tendencies

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ABSTRACT

Social anxiety and psychopathy have conceptually been linked to nearly opposite emotional, behavioral and endocrinological endophenotypes, representing social fearfulness and fearlessness, respectively. Although such a dimensional view has theoretical and practical implications, no study has directly compared social anxiety and psychopathy in terms of emotional experiences, relevant hormones (i.e. cortisol, testosterone) and behavioral tendencies (i.e. social approach-avoidance). Therefore, the present study examined 1) whether self-reported social anxiety and psychopathic traits are indeed anticorrelated, and 2) whether social anxiety, psychopathic traits, cortisol, testosterone and their interplay are differentially linked to social approach-avoidance tendencies. In a well-powered study, a sample of 196 healthy female participants, we assessed self-reported emotional and behavioral tendencies of social fear (i.e. social anxiety and social avoidance) and psychopathic traits (i.e. Factor I [interpersonal-affective deficit] and Factor II [impulsive behavior]). Furthermore, hormone levels were assessed, and approach-avoidance tendencies towards emotional (angry, happy) facial expressions were measured by means of a joystick reaction time task. Results confirmed that self-reported emotional tendencies of social anxiety and psychopathy Factor I (interpersonal-affective deficit) correlated negatively, but self-reported behavioral tendencies (social avoidance and psychopathy Factor II [impulsive behavior]) correlated positively. Furthermore, Structural Equation Modelling demonstrated that participants with higher social anxiety and higher cortisol levels showed an avoidance tendency towards happy faces, while participants with higher psychopathic traits showed an approach tendency towards angry faces. In sum, the notion that social anxiety and psychopathic traits are opposing ends of one dimension was supported only in terms of self-reported emotional experiences, but a comparable relationship with regard to behavioral and endocrinological aspects is debatable. The current findings stress the necessity to study emotional, endocrinological and behavioral factors in unison in order to better understand the shared and distinctive mechanisms of social anxiety and psychopathic traits.

1. Introduction

Social anxiety and psychopathy have been linked to opposite emotional, behavioral and endocrinological endophenotypes. Social anxiety is defined by elevated fear in social situations and avoidance (Rapee and Heimberg, 1997), and related to high cortisol and low testosterone levels (Giltay et al., 2012; Roelofs et al., 2009). Psychopathy, in contrast, is defined by an interpersonal-affective deficit including fearlessness (Factor I) and impulsive rule-breaking behavior (Factor II; for review see Hare and Neumann, 2008), and related to low cortisol and high testosterone levels (Stålenheim et al., 1998; Volman et al., 2016). These opposing characteristics might indicate that social anxiety and psychopathy are the outermost ends of one dimension ranging from social fearfulness to social fearlessness. One study among healthy participants found that self-reported social anxiety and psychopathic tendencies are negatively related (Hofmann et al., 2009). However, existing

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	Psychopathy	Social anxiety
Emotional endophenotypes	Social fearlessness	Social fearfulness
Behavioral endophenotypes	Social approach	Social avoidance
Endocrine endophenotypes	Low cortisol	High cortisol
	High testosterone	Low testosterone

Fig. 1. Graphical illustration of the hypothesized social fearfulness and social fearlessness dimensions and underlying characteristics.

evidence on its endophenotypes has primarily been based on separate investigations rather than combined studies. Furthermore, research concerning psychopathy mostly focused on men, so little is known about its manifestation in women (Verona and Vitale, 2018). In contrast, social anxiety is more prevalent and well-examined in women. A combined investigation of social anxiety and psychopathy, as well as their emotional, behavioral and endocrinological correlates in women may thus further our understanding of shared underlying mechanisms. Thus, the current study examined the link between social anxiety and psychopathy, and its relation with cortisol, testosterone and social approach-avoidance tendencies.

Social anxiety and psychopathy have both been related to dysfunctions in the processing of social stimuli and their responses towards them. During the processing of emotional faces, activations in neural emotion-processing networks, including fronto-amygdala circuits are increased in social anxiety (Brühl et al., 2014; Cremers and Roelofs, 2016) and decreased in psychopathy (Blair, 2019, 2003; Volman et al., 2016). Differences in emotion processing patterns might underlie social avoidance and aggression in individuals with social anxiety and psychopathy, respectively (e.g. Blair, 2019; Cremers and Roelofs, 2016). The Approach-Avoidance Task (AAT; Chen and Bargh, 1999; Roelofs et al., 2010; Solarz, 1960) directly assesses these emotion driven action tendencies thereby activating overlapping neural structures (Bramson et al., 2020; Volman et al., 2016, 2011). During the AAT, participants respond to pictures of emotional faces by pushing (i.e. avoidance) or pulling (i.e. approach) a joystick with reaction times serving as an indication of stimuli valence and dominant response. Healthy participants show faster approach tendencies of happy faces and faster avoidance tendencies of angry faces than vice versa (i.e., *congruency effect*; Phaf et al., 2014). However, socially anxious students were faster than non-anxious controls in avoiding both angry and happy faces (Heuer et al., 2007; Lange et al., 2008; Roelofs et al., 2010), whereas male psychopathic inmates were slower than controls in avoiding angry faces (von Borries et al., 2012).

Social anxiety, psychopathy and social approach-avoidance are furthermore affected by the steroid hormones cortisol and testosterone (Kaldewaij et al., 2016; Terburg et al., 2009). Cortisol and testosterone are synthesized by the hypothalamus-pituitary-adrenal (HPA) axis and hypothalamus-pituitary-gonad (HPG) axis, respectively, and work in antagonism facilitating opposing behavioral tendencies.[1] In response to social challenging situations, cortisol prepares an individual for active avoidance (Roelofs et al., 2005). Testosterone, on the other hand, inhibits the HPA-axis and facilitates social approach and dominance-seeking behavior (Enter et al., 2014; Radke et al., 2015; Terburg et al., 2009; Viau, 2002). Hormonal assessments have shown that stress-related cortisol is increased in social anxiety (Roelofs et al., 2009), whereas basal testosterone is increased in indviduals with psychopathy (Stålenheim et al., 1998). Moreover, male psychopathic offenders with higher baseline testosterone showed a reduction in activity between prefrontal and limbic regions when having to override the automatic tendencies to approach happy faces and to avoid angry faces on the AAT (Volman et al., 2016). In social anxiety disorder, cortisol administrations before the AAT lead to an increased event-related potential (P150) indicating increased vigilance to prepare for the avoidance of angry faces (van Peer et al., 2009). Testosterone administrations before the AAT lead to an increased approach tendency for angry faces in female participants (Enter et al., 2016), comparable to that in psychopathic inmates (von Borries et al., 2012). It has also been suggested that testosterone is only related to aberrant social behavior if levels of cortisol are low (i.e. *dual-hormone hypothesis*), but evidence is mixed (for review see Mehta and Prasad, 2015). Taken together, these findings suggest that cortisol primarily plays a role in social anxiety and avoidance, whereas testosterone might underlie the decreased control mechanisms during social approach in psychopathy.

The current study examined whether social anxiety and psychopathy can be conceptualized as two opposing ends of one dimension regarding their emotional, endocrine and behavioral endophenotypes (see Fig. 1). Little research has been conducted using female samples, however these samples of participants are overrepresented in studies on social anxiety (Staugaard, 2010; Verona and Vitale, 2018). Herefore, only female participants were recruited. We included 196 female participants who filled in self-reports of social anxiety and psychopathic traits, provided saliva for hormonal assessment and completed an AAT. First, we investigated whether social anxiety and psychopathic traits were negatively related to each other (Hofmann et al., 2009). Second, the interrelated roles of social anxiety, psychopathic traits, cortisol and testosterone on approach-avoidance behavior towards emotional faces were investigated using Structural Equation Modelling. We expected participants with higher social anxiety to show faster avoidance tendencies of both angry and happy faces (e.g., Roelofs et al., 2010). Additionally, we expected that higher endogenous pre-task cortisol levels would moderate these avoidance tendencies (van Peer et al., 2009). Furthermore, we expected that participants with higher psychopathic traits would be slower in avoiding angry faces (von Borries et al., 2012), and that higher endogenous pre-task testosterone levels would moderate these approach tendencies (Volman et al., 2016). Finally, we explored the dual-hormone hypothesis, i.e. the interaction between cortisol and testosterone, and its relationship with approach-avoidance tendencies, social anxiety and psychopathic traits without a specific hypothesis.

2. Material and methods

The current study is part of a larger research project partially reported elsewhere (Peeters et al., 2020). Here, only the material relevant for answering the current research questions is described. A complete overview of the study material is described in the Supplementary material.

2.1. Participants

A sample of healthy female participants ($N = 228$) was recruited via the participant pool of Radboud University in Nijmegen. We only included participants on contraceptives in order to limit confounding effects of hormonal cycle. Participants were excluded if they had a neurological or psychiatric disorder, and/or used neuroleptics or psychopharmaceutic medicine. For the current study, thirty-one participants were excluded from the analyses either due to missing self-report

[1] In women, the final component of the HPG-axis is not the gonad but the ovary and the adrenal gland (Burger et al., 2002)

data ($n = 28$), technical problems ($n = 3$) or not meeting inclusion criteria ($n = 1$). The final sample consisted of 196 participants between 18 and 33 years of age (M[SD] = 20.53[2.49]).

2.2. Procedure

One week prior to testing, participants were asked to refrain from drinking alcohol and using psychoactive drugs. During the testing day, participants were instructed to refrain from exercise, drinking caffeine and alcohol, using drugs and smoking. Participants gave written informed consent in accordance with the study description. Participation was compensated with 3 course credits or €20 for non-psychology students.

The study consisted of two parts, namely an online survey and a lab session. The online survey included the Liebowitz Social Anxiety Scale (Liebowitz, 1987) and the Psychopathic Personality Inventory (Lilienfeld and Andrews, 1996) which, took about 30 min and was filled in at home 3–7 days before coming to the lab. In the lab, participants were welcomed at the same time as a confederate pretending to be another participant. After filling in more questionnaires, the first saliva samples for hormone assessment were collected by passive drool, after which participants completed the Approach-Avoidance Task (Roelofs et al., 2010). For the remainder of the experiment, participants completed two more computer tasks and provided three more saliva samples (see supplements for details). The duration of the whole session was 2 h.

2.3. Liebowitz Social Anxiety Scale (LSAS; Liebowitz, 1987)

The LSAS measures an individual's fear of social situations and their tendency to avoid them (e.g., going to a party, talking to people in authority). For 24 social situations, participants indicated both the level of fear and the likelihood to avoid those situations by using two separate Likert scales ranging from 0 (*none/ never*) to 3 (*severe/ usually*). Subscale scores for anxiety and for avoidance were summed into a total score. In the current study, internal consistency was excellent for the subscales anxiety ($\alpha = 0.91$) and avoidance ($\alpha = 0.89$), as well as for the total scale ($\alpha = 0.94$).

2.4. Psychopathic Personality Inventory (PPI; Lilienfeld and Andrews, 1996)

The PPI assesses psychopathic traits using eight subscales: Machiavellian egocentricity, social potency, fearlessness, coldheartedness, impulsive nonconformity, blame externalization, carefree nonplanfullness, and stress immunity. In total, 187 items have to be answered on a 4-point Likert scale ranging from 1 (*false*) to 4 (*true*). Following a factor analysis by Benning et al., (2003), Factor I and Factor II were computed by summing the subscales for social potency, fearlessness, and stress immunity into Factor I ($\alpha = 0.9$) and the subscales impulsive nonconformity, blame externalization, Machiavellian egocentricity, and carefree nonplanfullness into Factor II ($\alpha = 0.92$), respectivly. The subscale coldheartedness was part of the total score only (Benning et al., 2003). In the current sample, the internal consistency of the total score was excellent with $\alpha = 0.91$.

2.5. Hormonal assessment

Three saliva samples were obtained at − 15, + 45 and + 60 min with reference to the start of the AAT. In the current study, only the − 15 min, pre-task sample, was used as we were interested in the role of pre-task hormonal levels. Salicap containers were used, which were subsequently stored at − 20 degrees Celsius before being sent to Dresden LabService GmBH (Dresden, Germany) and being analyzed by them. In the lab, salicaps were thawed and centrifuged at 3,000 rpm for 5 min, resulting in a clear supernatant of low viscosity. Salivary concentrations of cortisol and testosterone were measured using the commercially available chemiluminescence immunoassays (IBL International, Hamburg, Germany).

Due to logistical constraints, we did not have a set time during the day for lab testing sessions. Accordingly, participants were tested between 8.20 AM–5.30 PM ($M_{\text{time of testing}} = 12.08$ PM). As cortisol is known to fluctuate on a diurnal curve, we checked whether time of day affected cortisol levels. Participants were separated into two groups based on a median-split of time of testing (i.e. 11.40 AM). A two-sample t-test between the morning ($M = 14.52$, $SD = 9.05$) and the afternoon groups ($M = 14.62$, $SD = 9.44$) was non-significant with $t(194) = 0.08$, $p = .94$, indicating that pre-task cortisol levels did not differ significantly between participants tested in the morning and those tested in the afternoon. Thus, for the main analyses we did not differentiate between morning and afternoon testing.

2.6. Approach-Avoidance Task (AAT; Roelofs et al., 2010)

The AAT measures automatic approach-avoidance tendencies towards happy, angry and neutral faces. Single pictures were presented on a computer screen and participants responded, as quickly as possible, to the facial expressions by either pulling (i.e. approaching) or pushing (i.e. avoiding) a joystick. To stress the idea of approaching and avoiding the stimuli, pictures first appeared medium sized, but were enlarged when pulling and shrank when pushing the joystick. A correct response was defined by moving the joystick in the required direction until the picture disappeared. The AAT consisted of six blocks in which participants were instructed to push or pull the pictures depending on the expressed emotions. Each block contained only two emotional expressions, so that during one block participants were instructed to pull e.g., all angry looking faces and to push e.g., all happy looking faces. All combinations between facial expressions and joystick movements were combined. Each block consisted of 64 trials, in which 32 faces with a direct gaze and 32 with an averted gaze were presented. Presentation of the blocks and presentation of stimuli within the blocks was pre-randomized. Before each block, participants completed 16 practice trials. In total, participants completed 384 trials. Task completion took roughly 20 min.

2.7. Statistical approach

Data were analyzed using the statistical software R (version 3.6.2; R Core Team, 2019) and RStudio (version 1.2.5033, RStudio Team, 2019). First, to examine the relationship between social anxiety and psychopathic traits Pearson's correlations were computed using the function cor.test of the package psych (version 1.8.12; Revelle, 2018).

As a manipulation check, the typical AAT congruency effect was verified with F_1 x F_2 repeated measure analysis of variance (rmANOVA; Clark, 1973) by using the function aov_mean of the package afex (version 0.27.2; Singmann et al., 2020). Post-hoc comparisons were conducted using the function emmeans of the package emmeans (version 1.4.6; Lenth, 2020).

In order to analyze the second research question concerning the interrelationships between social anxiety, psychopathic traits, cortisol levels and testosterone levels on automatic approach-avoidance behavior, Structural Equation Model (SEM) was used[2] using the function sem of the package lavaan (version 0.6.6; Rosseel, 2012).

[2] The original plan was to use linear mixed-effect models to analyze the unaggregated trial-level AAT data as a function of movement, emotion, gaze direction, social anxiety, psychopathic traits, cortisol, testosterone levels, as well as their interactions. However, we were unable to fit this model, as well as simplified models due to persistent problems with model estimation. As a consequence, we first conducted a F_1 x F_2 rmANOVA in order to verify the typical AAT congruency effect. F_1 x F_2 tests have a lower likelihood on Type I error rates as compared to usual rmANOVA (Clark, 1973). In order to examine the main research question, we then adopted the reported SEM framework.

Table 1
Descriptives and Bivariate Correlations of Questionnaires using Holm adjustment (N = 196).

Measure	Descriptives		Correlations						
	M (SD)	Range	1	2	3	4	5	6	7
1. LSAS total	31 (18)	0–111	–						
2. LSAS anxiety	16 (10)	0–59	.96***	–					
3. LSAS avoidance	14 (9)	0 – 52	.95***	.82***	–				
4. PPI total	327 (37)	248–441	-0.19	-0.23*	-.12	–			
5. PPI I	126 (19)	72–182	-0.56***	-.57***	-.51***	.71***	–		
6. PPI II	158 (25)	104–237	.18	.13	.23*	.83***	.25***	–	
7. Cortisol	15 (9)	3–46	-0.03	-0.05	.00	-0.01	-0.05	.06	–
8. Testosterone	26 (18)	3–102	-0.01	-0.04	.02	.02	.04	-0.03	.12

* statistically significant at $p < .05$
*** statistically significant at $p < .001$.

3. Results

3.1. The relationship between self-reported social anxiety and psychopathic traits

Pearson's correlations were used to test whether self-reported social anxiety and psychopathic traits were negatively related to each other, while correcting for multiple tests with Holm adjustments. The correlation between LSAS total score and PPI total score was not significant ($r = -0.19$, $p = .14$). However, significant correlations between the subscales did emerge. That is, both the LSAS anxiety and avoidance subscale scores correlated significantly negatively with PPI Factor I ($r = -0.57$, $p < .001$ and $r = -0.51$, $p < .001$, respectively) showing that individuals who reported more fear and avoidance tendencies in social situations reported lower scores on Factor I, thus reduced social potency, reduced stress immunity and reduced fearlessness. Against expectations, a significant positive correlation between LSAS avoidance scores and PPI Factor II was found ($r = 0.23$, $p = .02$) indicating that participants who reported avoiding social situations also reported higher scores on Factor II, meaning increased impulsive behavior, blame externalization, machiavellian egocentricity, and carefree nonplanfullness. See Table 1 for a complete correlation matrix of all predictors of interest.

3.2. Verifying the typical AAT effects

F_1 x F_2 rmANOVAs were conducted in order to verify the typical AAT congruency effect. That is, two ANOVAs were conducted with one aggregating across participants (F_1) and the other aggregating across stimuli (F_2). In both, F_1 and F_2, reaction time was entered as dependent variable, and the factors emotion, movement and gaze direction, as well as the interactions thereof, were entered as independent variables. According to Clark (1973), an effect can only be interpreted as significant if it is significant in both F_1 and F_2.

The typical AAT congruency effect was found as indicated by a significant interaction between emotion and movement in both F_1, $F(1.96, 383.13) = 32.24$, $p < .001$, and F_2, $F(2, 14) = 56.15$, $p < .001$. Follow-up analyses indicated that the reaction times for pulling the joystick were signigicantly faster for happy faces compared to the reaction times of pushing the joystick, while the reaction times for pushing the joystick were significantly faster for angry and neutral faces compared to the reaction times of pulling the joystick (all p's < 0.001). Furthermore, the reaction times for pulling the joystick waere significantly faster for happy faces than for angry faces (both p's < 0.05). Given that none of the relevant effects involving gaze direction were significant for both F_1 and F_2 (i.e. main effect for gaze was significant in F_1, $p < .001$, but not in F_2, $p = .38$, all interaction effects involving gaze had p's > 0.06), we aggregated the effect scores across averted and direct gaze for the subsequent SEM.

3.3. The role of social anxiety, psychopathic traits, cortisol and testosterone in the AAT

SEM was conducted in order to examine whether social anxiety, psychopathic traits, cortisol levels and testosterone levels, as well as the interactions relate to different approach-avoidance tendencies on the AAT. AAT effect scores of happy, angry and neutral faces were entered as dependent variables, which were calculated as followed: The outermost 0.5% trial-level reaction times from the top and the bottom of the overall distribution were winsorized i.e. replacing the most extreme values by the closest unwinsorized value (Kokic and Bell, 1994). Next, reaction times were aggregated across movement (push, pull) and emotion (happy, angry, neutral). For each emotion, aggregated push scores were subtracted from aggregated pull scores yielding three effect scores per participant. Importantly, positive scores indicate that the participant was generally faster to pull than to push this emotion (approach). Negative scores indicate that the participant was generally faster to push than to pull this emotion (avoidance). The predictors social anxiety, psychopathic traits, cortisol levels, testosterone levels, all six two-way interactions and the two three-way interactions social anxiety x cortisol x testosterone and psychopathic traits x cortisol x testosterone were entered into the model. In order to explore the dual-hormone hypothesis, the interactions between cortisol x testosterone levels were included (Mehta and Prasad, 2015). Interactions, rather than ratios, are recommended as the analytical technique if the interdependent role of two hormones on a behavioral outcome is examined (Chen et al., 2015), furthermore it enables a more detailed examination of these underlying relationships (Sollberger and Ehlert, 2016). All predictors were standardized. Interaction terms were created by multiplying the respective standardized predictors with each other, which were then entered into the model as separate variables. In order to match variances, the dependent variables were divided by 10. In total 113 parameters were fitted using maximum likelihood estimation, namely 36 regression coefficients, 15 intercepts, 15 covariances and 47 residual correlations to account for the interdependence of the interaction terms.

The absolute fit of the model was good as indicated by a non-significant chi-square, $\chi 2$ (22) = 24.21, $p = .336$, a Root Mean Square Error of Approximation (RMSEA; Steiger, 1990; Steiger and Lind, 1980) below.05, RMSEA = 0.023, and a Goodness of Fit Index (GFI; Jöreskog and Sörböm, 1981) above 0.9, $GFI = 0.985$. The incremental fit, i.e. the Comparative Fit Index (CFI) was also above the cut-off value of.95 (Bentler, 1995; $CFI = 0.988$). With regard to the individual regression pathways, the amount of variance explained was 8.2% for happy faces, 8.3% for angry faces, and 4.4% for neutral faces. Three significant regression effects were found, namely an interaction between social anxiety and cortisol levels ($\beta = -0.21$, $p = .007$, CI [−3.21; −0.52]), a main effect of testosterone levels ($\beta = 0.14$, $p = .041$ =, CI [0.05; 2.21]) on the effect scores of happy faces, as well as a main effect of psychopathic traits ($\beta = 0.21$, $p = .003$, CI [0.56; 2.69]) on the effect scores of angry faces. None of the other predictors was significant. Excluding outliers, i.e. participants who deviated more than + /- 3 SD from the

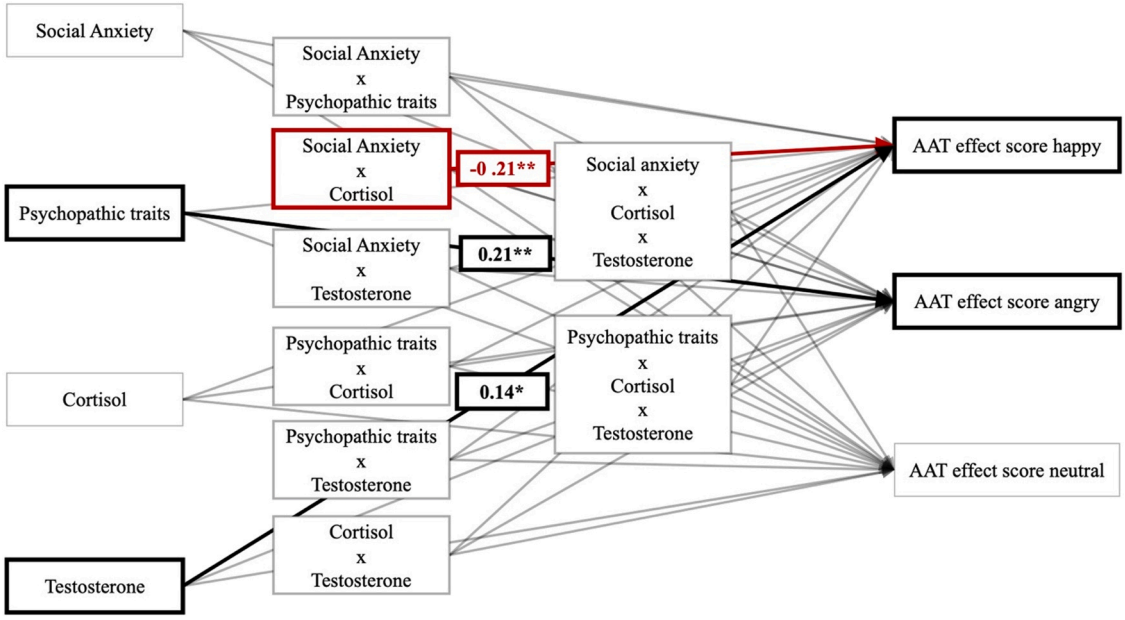

Fig. 2. Simplified illustration of the Structural Equation Model on the interrelationship between social anxiety, psychopathic traits, cortisol and testosterone on AAT effect scores. For clarity reasons, variances and covariances that were tested in the model are not presented in this figure. Significant predictors and paths are printed in bold with positive relationships in black and negative relationships in red. AAT = Approach-Avoidance Task. * statistically significant at $p < .05$; ** statistically significant at $p < .01$.

mean of any independent variable ($n = 11$), did not change the significant pathways. See Fig. 2.

The interaction between social anxiety and cortisol levels means that social anxiety is associated with different effect scores for happy faces in individuals with different levels of endogenous pre-task cortisol. As shown in Fig. 3, individuals with lower cortisol levels the effect scores for happy faces are generally in the positive range irrespective of their level of social anxiety. Thus, individuals with lower levels of endogenous pre-task cortisol and varying levels of social anxiety are generally faster to pull than to push happy faces, which is in line with the congruency effect postulating an automatic tendency to approach happy faces. However, effect scores decrease in participants with higher cortisol levels as levels of social anxiety increase. This means that participants with higher endogenous pre-task cortisol levels and higher social anxiety are slower in pulling happy faces than pushing them, which indicates a tendency to avoid happy faces. This finding is in line with our hypothesis concerning the moderating role of cortisol on approach-avoidance tendencies in social anxiety.

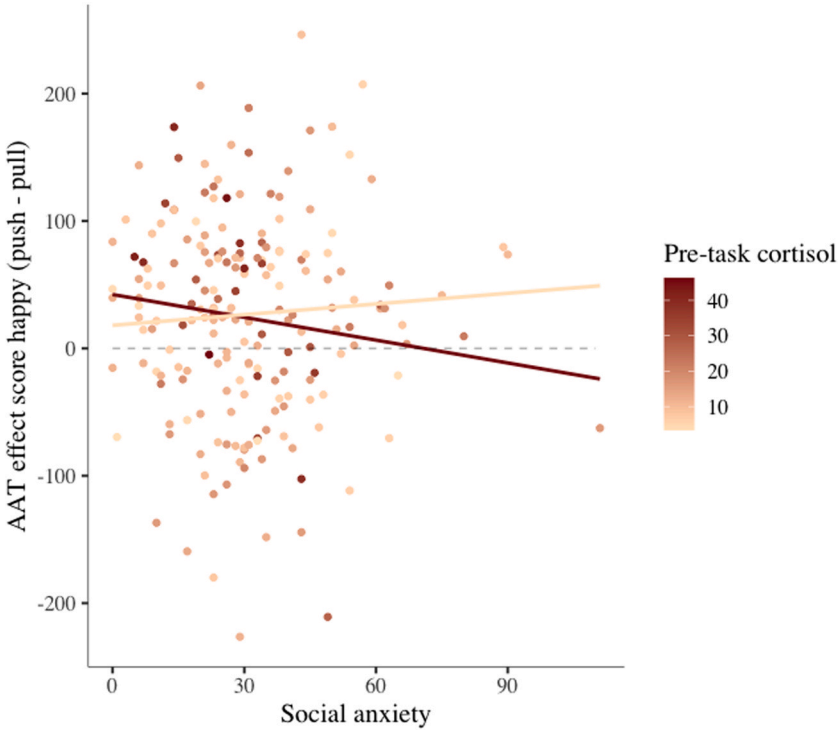

Fig. 3. Significant Structural Equation Model interaction between social anxiety and cortisol on AAT effect scores of happy faces. Positive effect scores indicate a stronger approach tendency and negative effect scores indicate stronger avoidance tendency. Each dot represents one participant. Color of dots represent level of pre-task cortisol. For displaying purposes, participants have been grouped into high and low cortisol in order to draw lines as a function of cortisol and social anxiety on effect scores. AAT = Approach-Avoidance Task.

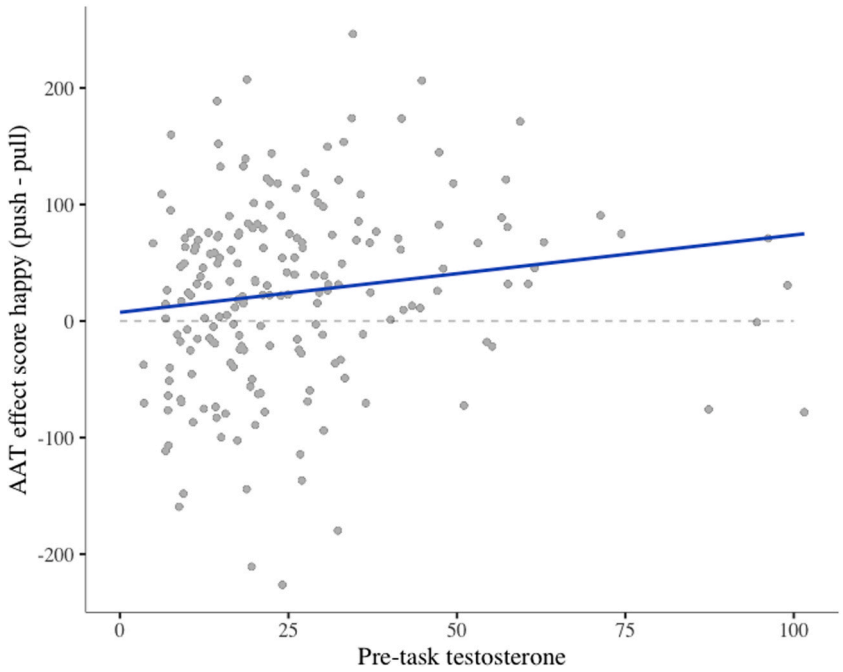

Fig. 4. Significant Structural Equation Model main effect of testosterone on AAT effect scores of happy faces. Positive effect scores indicate a stronger approach tendency and negative effect scores indicate a stronger avoidance tendency. Each dot represents one participant. AAT = Approach-Avoidance Task.

Furthermore, the significant main effect of testosterone levels on the effect scores of happy faces indicated that with increasing levels of endogenous pre-task testosterone across participants, higher effect scores were observed. As indicated by Fig. 4, effect scores are close to zero for participants with lower endogenous pre-task testosterone levels indicating slower pull than push movements for happy faces. A diminished approach tendency of happy faces is contrary to the congruency effect. Participants with higher levels of endogenous pre-task testosterone have increasingly positive effect scores indicating faster pull than push movements for happy faces. An approach tendency of happy faces is in line with the congruency effect.

Finally, the significant main effect of psychopathic traits on the effect scores of angry faces indicated that increasing levels of psychopathic traits are accompanied by an increase in effect scores. As Fig. 5 shows, on average the effect scores are negative for participants with lower psychopathic traits, meaning that angry faces were pushed faster than pulled. This indicates that individuals with lower psychopathic traits had the tendency to avoid angry faces, which is in line with the congruency effect. With increasing levels of psychopathic traits, effect scores become positive, thus angry faces were slower pushed than they were pulled. This indicates that individuals with higher levels of psychopathic traits have a tendency to approach angry faces, which is in

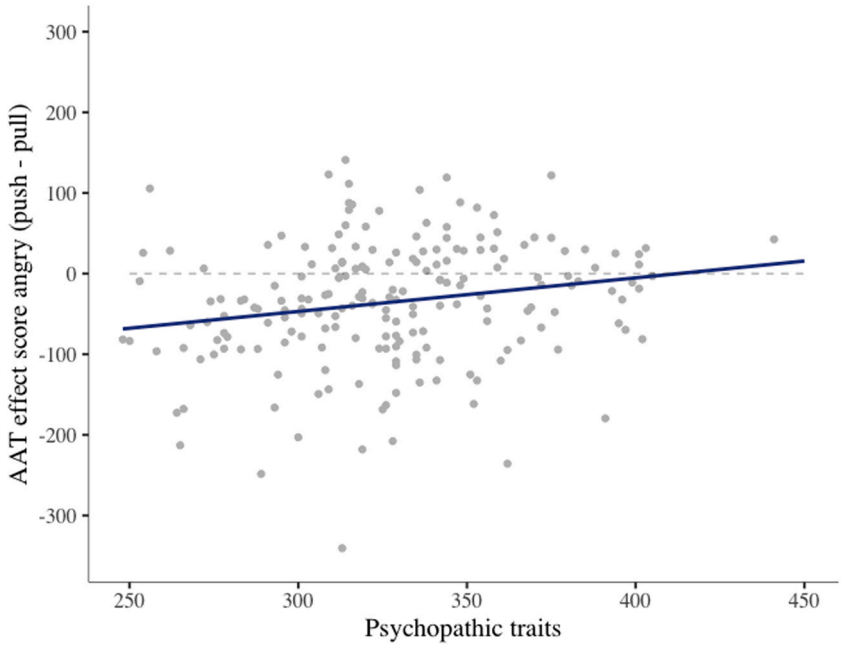

Fig. 5. Significant Structural Equation Model main effect of psychopathic traits on AAT effect scores of angry faces. Positive effect scores indicate a stronger approach tendency and negative effect scores indicate a stronger avoidance tendency. Each dot represents one participant. AAT = Approach-Avoidance Task.

line with our hypothesis concerning decreased avoidance tendencies in individuals with increased psychopathic traits.

There were no other significant effects. Therefore, our remaining hypotheses were not supported. To be precise, social anxiety alone was not significantly related to altered approach-avoidance tendencies towards either happy or angry faces, and testosterone levels did not significantly moderate approach-avoidance tendencies in individuals with psychopathic traits. Since none of the effects involving the interaction between cortisol x testosterone levels were significant, no support for the dual-hormone hypothesis was found.

4. Discussion

The current study examined the relation between social anxiety and psychopathic traits as a function of their emotional, endocrinological and behavioral endophenotypes in female participants. We found that self-reported social anxiety was negatively correlated with psychopathy Factor I (interpersonal-affective deficit), whereas social avoidance was positively correlated with psychopathy Factor II (impulsive rule-breaking). With regard to the Approach-Avoidance Task (AAT), participants with higher social anxiety and higher levels of endogenous pre-task cortisol tended to avoid happy faces, whereas participants with higher psychopathic traits tended to approach angry faces. These findings provide partial support for a social fearfulness-fearlessness dimension given that the emotional characteristics of self-reported social anxiety and psychopathy are indeed opposing. The classification of associated behavioral and endocrinological tendencies was more complex.

In line with our hypothesis, the self-reported emotional characteristics of social anxiety and psychopathy were indeed anticorrelated as indicated by a negative relation between the social anxiety subscale and the interpersonal-affective psychopathy (Factor I) subscales. This might indicate that the interpersonal-affective component of psychopathy is –among others –characterized by social fearlessness. According to evolutionary psychology, social anxiety fosters behavior which ensures group belongingness (Gilbert, 2001). An indifference towards social evaluation might play a role in the transgression of social norms. The self-reported behavioral aspect of social anxiety (social avoidance) indeed showed a significant negative correlation with the interpersonal-affective deficit. Thus, uninhibited behavior is likely to be an expression of the interpersonal-affective deficit. In contrast to our hypothesis, however, self-reported social avoidance and the impulsive, rule-breaking aspect of psychopathy (Factor II) showed a significant positive correlation. This, at first sight, unexpected relation might be explained by the fact that both an unwillingness to interact and harmful actions can be viewed as antisocial behaviors. Although driven by different motives, both behaviors ultimately reflect an action obstructing prosocial behavior. It is this action component that may explain the overlap between these behavioral subscales of psychopathy and social anxiety. These opposing correlations for the emotional and behavioral subscales likely explain why the total scores for social anxiety and psychopathy were not significantly correlated (unlike). Moreover, the strength of the remaining correlation coefficients indicates that social anxiety was strongly related to social avoidance, whereas there was only a weak correlation between the psychopathy subscales, hinting at an incoherence between psychopathy Factor I and Factor II. Previous work also demonstrated that Factor I and II differentially relate to anxiety, fear and distress (Derefinko, 2015), though the debate on whether psychopathy is best defined by two, three or four factors is ongoing (Cooke and Michie, 2001; Hare and Neumann, 2008; Vitacco et al., 2005). For the current study, a differentiation between self-reports of emotional and behavioral characteristics of psychopathy were meaningful and of high reliability (Cronbach's alpha ranging from.9 to.92). Thus, for future studies it may be relevant to take that distinction into account.

The results of the AAT confirmed that both social anxiety and psychopathic traits are characterized by deviating behavioral tendencies, and disclosed specific approach-avoidance tendencies. A wealth of research has shown that healthy participants typically show a tendency to avoid angry faces (versus neutral and happy faces) and tend to approach happy faces (as compared to angry and neutral faces; for review see Phaf et al., 2014). In line with our expectations, reaction times for approaching happy faces and avoiding angry faceswere affected by individual differences in social anxiety scores and psychopathic traits. Participants with higher social anxiety scores and cortisol levels showed a tendency to avoid happy faces, while participants with higher psychopathic traits showed a tendency to approach angry faces. These findings generally fit into the hypothesized fearfulness-fearlessness dimension, underlining social avoidance and social approach as behavioral tendencies for social anxiety and psychopathy, respectively.

With increasing levels of social anxiety, participants with higher levels of pre-task cortisol tended to avoid happy faces during the AAT. This effect is partly in line with previous work indicating that cortisol levels modulates social avoidance in high socially anxious individuals (van Peer et al., 2007; Roelofs et al., 2009). In contrast to the latter study and to other behavioral work (Heuer et al., 2007; Lange et al., 2008; Roelofs et al., 2010), avoidance in our socially anxious individuals was only observed for happy faces and not for angry faces. This differential finding may have several reasons. Firstly, Roelofs and colleagues (2010) also observed that the increased avoidance for happy faces in high socially anxious individuals was persistent even when the gaze direction was manipulated. In the averted gaze conditions, happy faces were still avoided whereas the avoidance of angry faces diminished, emphasizing the robustness of happy-avoid tendencies in high socially anxious individuals. Accordingly, socially anxious individuals are thought to perceive smiles as less positive due to their fear of interactions and social evaluation (Weeks et al., 2008), as well as due to negative interpretational biases (e.g., 's/he is laughing about me', Amin, Foa, & Coles, 1998). Perhaps angry faces (which in the current study were avoided irrespective of the degree of socially anxiety) leave less room for such interpretational biases and were therefore less prone to initiate individual approach-avoidance differences in this sample of healthy participants. In line with this interpretation, patients with social anxiety disorder were previously found to explicitly rate happy faces as less approachable than healthy controls, whereas there was no difference in ratings for angry faces (Campbell et al., 2009). The impression that a smiling person is unapproachable may also slow down automatic approach tendencies. It should be noted that in our study, social anxiety alone was not related to stronger avoidance tendencies, but only in interaction with pre-task cortisol levels. Accordingly, this might indicate that endogenous cortisol levels serves as a biological state marker of social anxiety. Only those socially anxious participants who were actually stressed might show social avoidance tendencies. This might also explain why some previous research that did not control for biological markers, did not find increased avoidance tendencies in social anxiety (Asnaani et al., 2014; Struijs et al., 2018). The finding that social avoidance and cortisol levels were related to social anxiety supports the hypothesis that these behavioral and endocrinological processes may play a role in social fearfulness.

In contrast to social anxiety, higher levels of psychopathic traits were related to slowed avoidance to angry faces. This finding is in line with our hypothesis, as well as with the hypothesis of von Borries et al. (2012), who found a similar pattern in incarcerated psychopaths when compared to healthy male participants. Von Borries et al. (2012) interpreted these findings to indicate that individuals with higher psychopathic traits may perceive angry faces as less threatening and thus lack the automatic tendency to avoid them. Anger typically leads to distress or fear in the perceiver thus, eliciting avoidance tendencies in order to prevent negative interactions (Marsh et al., 2005). Individuals with psychopathy may either have difficulty recognizing angry expressions (Dawel et al., 2012) or lack the automatic emotional reactions that are evoked by anger (Blair, 2003). As a consequence, automatic avoidance

tendencies might be impaired. In the current study, a linear trend towards the approach of angry faces was found, which might suggest that social approach is the behavioral endophenotype of psychopathy in both men and women. In contrast to our hypothesis, however, we found no support for the role of pre-task testosterone levels in psychopathic tendencies and these approach tendencies. Previous work with the AAT in samples that showed aggressive behavior found endogenous testosterone levels to modulate neural mechanisms but not behavior (Kaldewaij et al., 2016; Volman et al., 2016). Perhaps the effects of endogenous testosterone levels in a healthy sample are generally weak and more extreme stimuli or situations are needed for testosterone to modulated approach tendencies in relation to aggression.

One unexpected finding was that participants with lower pre-task testosterone levels tended to approach happy faces slower, whereas participants with higher pre-task testosterone levels showed the usual approach tendencies towards happy faces. The main function of testosterone is to promote social status (Eisenegger et al., 2011). If levels of testosterone are decreased, status promotion might not be pursued and related actions might be slower. Interestingly, socially anxious individuals with higher levels of pre-task cortisol showed a similar avoidance tendency in the current study. Given that endogenous testosterone levels are lower in individuals with social anxiety disorder (Giltay et al., 2012), the current findings raise the question of whether low levels of testosterone may act as a precursor of social anxiety since they relate to the same automatic actions. Although this implies an interaction of cortisol and testosterone levels, our study provided no evidence for such a dual-hormone explanation (Mehta and Prasad, 2015; Terburg et al., 2009). Future research is clearly needed to reveal the complex roles of hormones, approach-avoidance tendencies and development of social fearfulness and fearlessness.

Several strengths and limitations of this study should be considered. The current study was one of the first that took a dimensional approach to social anxiety and psychopathic traits by combining self-reports, behavioral measures and hormone assays. Another strong point of the study is the large sample-size allowing for individual difference analyses. Since psychopathy is understudied in women (Verona and Vitale, 2018), the current study offers a valuable frame of reference regarding the manifestation of psychopathic traits and its endophenotypes in a sample of female participants. However, the fact that we only tested healthy female students means that the current results cannot be generalized to male participants or clinical populations. Additionally, our findings should be complemented with different measurements of social anxiety and psychopathy in the future to be able to link the various operationalizations of those two concepts. Furthermore, the operationalization of approach-avoidance behavior in response to static pictures in the task we used can only serve as a proxi to real life behavior. Although the AAT has been proven to assess and modify real life approach-avoidance behavior (Rinck and Becker, 2007) its reliability has been shown to be moderate (Phaf et al., 2014; Staugaard, 2010). Social situations in real life are more complex, influenced for example by expectations, prior experiences and motives for action. Future research should take that into account. Finally, Structural Equation Modelling is not ideal to analyze the AAT data. Due to persistent problems with model estimation, we had to deviate from our original analyses plan of using linear mixed-effect models. In future research, more sensitive analyses should be performed.

5. Conclusion

In sum, our results only partly support the notion that social anxiety and psychopathy can be conceptualized as two outermost ends of a social fearfulness-fearlessness dimension. As far as self-reported fear is concerned, we found the expected negative association with the interpersonal-affective aspects of psychopathy. This relation only held for the emotional aspects and not for the self-reported behavioral aspects of social fear and psychopathy. The behavioral and endocrine patterns did not support the dimensionality notion in a fully symmetrical fashion. In line with the hypotheses, social anxiety related to social avoidance tendencies and cortisol levels, and psychopathy related to social approach tendencies but without a relation to testosterone levels. Together this pioneering study stresses the necessity to study emotional, behavioral and endocrinological factors in unison in order to advance our understanding of shared and differential mechanisms underlying social anxiety and psychopathic traits.

Declaration of Competing Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.psyneuen.2021.105207.

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