Chapter 5

Motivational modulation of the hormone-aggression link: Effects of approach/avoidance postures on the association between salivary testosterone/cortisol and aggressive impulses

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Abstract

High testosterone combined with low cortisol is associated with increased approach motivation and aggression (e.g., Terburg, Morgan, & van Honk, 2009). The present study investigated whether this hormone-aggression link is modulated by situational increases in avoidance motivation. Because aggression is approach-oriented, we predicted that high testosterone/low cortisol would be associated with aggression when participants assumed approach-oriented postures, but not when participants assumed avoidance-oriented postures. To test this prediction, participants’ \((N = 199)\) aggressive impulses were assessed while they were randomly assigned to leaning forward (approach), leaning backward (avoidance), or a sitting straight (control) posture after recalling an anger-provoking situation. Participants’ testosterone and cortisol levels were assessed from salivary samples at the start and the end of the study. The results showed that high testosterone/low cortisol response levels were associated with more aggressive impulses when participants assumed an approach posture, but not when participants assumed control or avoidance postures. Unexpectedly, the effects of the approach posture differed from the control posture, but not from the avoidance posture. There was no evidence that the motivation-related postures modulated the link between baseline hormones and aggression. These findings indicate that motivation may dynamically modulate the pathway whereby hormones are translated into aggression.
Introduction

Human aggression is any behavior directed toward someone else that is carried out with the immediate intent to cause harm (Anderson & Bushman, 2002). Aggression takes a tremendous toll on society, both directly, by causing agony and suffering, and indirectly, through the costs of protecting, treating, and compensating victims. It is therefore vital to learn more about the basic mechanisms that cause aggression and to find ways of channeling people’s aggressive impulses towards more constructive ends. Prior research has shown that the combination of high testosterone and low cortisol is associated with increased aggression (Mehta & Josephs, 2010; Terburg, Morgan, & van Honk, 2009). However, this hormone-aggression association has not been consistently observed (Denson, Mehta, & Ho Tan, 2013; Eisenegger, Naef, Snozzi, Heinrichs, & Fehr, 2010; Mazur & Booth, 2014; Scerbo & Kolko, 1994; Schulz, Halperin, Newcorn, Sharma, & Gabriel, 1997), suggesting that the pathway from hormones to aggression is susceptible to modulating influences. In the present research, we consider whether one such influence is formed by basic motivations towards approach and avoidance. Specifically, we examine whether bodily postures related to approach and avoidance might modulate the hormone-aggression link.

Hormonal Influences on Aggression

One key player in the neuroendocrine systems that underlie behavioral aggression is testosterone, the end product of the hypothalamus-pituitary-gonadal (HPG) system. A large literature supports a positive relation between testosterone and aggression both in males (Archer, Graham-Kevan, & Davies, 2005), and females (Assari, Caldwell, & Zimmerman, 2014). Across naturalistic and laboratory settings, baseline testosterone levels are positively related to aggressive behavior, such as increased risk of a chronic antisocial lifestyle (Yildirim & Derksen, 2012), and causing more harm to co-players in the lab (Burnham, 2007; Mehta & Beer, 2010). Furthermore, experimentally administrating testosterone increases aggression (Zak et al., 2009).

The influence of testosterone on aggression is modulated by other hormones, in particular, cortisol, the end product of the hypothalamus-pituitary-adrenal axis (HPA). Although cortisol is mostly known for its positive relation with anxiety and depression (Schulkin, 2007), low levels of baseline cortisol are related to increases in aggression (McBurnett, Lahey, Rathouz, & Loebler, 2000). Among young men, lower baseline cortisol levels in saliva (McBurnett et al., 2000; Shoal, Giancola, & Kirillova, 2003), and plasma (Poustka et al., 2010), as well as a lower cortisol awakening responses (Platje et al., 2013) are related to increased aggressive behavior. Moreover, people who have the combination of high baseline testosterone, and low baseline cortisol are the most aggressive (Montoya, Terburg, Bos, & van Honk, 2012; Popma et al., 2007; Sherman, Lerner, Josephs, Renshon, & Gross, 2016; Terburg et al., 2009; van Honk, Harmon-Jones, Morgan, & Schutter, 2010).
Hormone-Basic Motivations and Aggression

The interactive effects of testosterone and cortisol on aggression may be explained by a common biological mechanism. There is a close interplay between the HPG and HPA axes and their end products, such that testosterone inhibits HPA functioning, whereas cortisol inhibits HPG functioning. Furthermore, both hormones influence activation of the amygdala (LeDoux, 2000; Nguyen et al., 2016), which subsequently facilitates motivational behavior. Specifically, the production of testosterone is responsible for the facilitation of fight/approach behavior, and the production of cortisol for the facilitation of flight/avoidance behavior (Schulkin, 2007). The combination of high testosterone and low cortisol thus facilitates the approach system, while inhibiting the avoidance system, a motivational combination conducive to aggression. Indeed, elevated baseline testosterone promotes increased attention to threat (van Honk et al., 1999), and testosterone administration increased approach behavior towards threatening stimuli (Enter, Spinhoven, & Roelofs, 2014). Conversely, stress related elevated cortisol is associated with less attention to threat (Roelofs, Bakvis, Hermans, van Pelt, & van Honk, 2007), and administration and high baseline levels of cortisol to avoidant behavior (Putman & Roelofs, 2011; Tops & Boksem, 2011; van Peer et al., 2007).

The positive relation between approach motivation and reactive aggression is well established in behavioral research (Carver & Harmon-Jones, 2009). For instance, people with higher levels of trait anger, a personality disposition linked to aggressiveness, are higher on general approach motivation, and display increased approach towards threatening social stimuli (Harmon-Jones, 2007). Moreover, higher trait anger is related to faster approach than avoidance movements to angry faces with a direct gaze, but not to angry faces with an averted gaze or smiling faces (Veenstra, Schneider, Bushman, & Koole, 2016, Chapter 3). Notably, the aggressive tendencies of people with high trait anger is moderated by behavioral inductions of avoidance motivation. For instance, people with higher levels on trait anger no longer displayed more state anger and aggression when they adopted an avoidance instead of approach related seating posture, i.e., when they leaned backward instead of forward on a chair (Veenstra, Dillon, Domachowska, Bushman, Schneider, and Koole, unpublished results, Chapter 4). Avoidance-related behaviors thus attenuate aggressive tendencies among people whose personality predisposes them towards aggression (Koole & Veenstra, 2015, Chapter 8).

Given that avoidance-related behavior can inhibit aggressive tendencies due to personality, it is conceivable that avoidance-related behavior can also inhibit aggressive tendencies due to hormonal influences. Indeed, hormones and behavior have reciprocal influences (Carré & Olmsted, 2015; Das & Sawin, 2016; Price, Peterson, & Harmon-Jones, 2012). For instance, men respond to sexual arousal (Archer, 2006), and increased sexual activity (Das & Sawin, 2016) with increases of testosterone. Moreover, in competitive interactions, losing instead of winning results in larger increases of testosterone (Carré & Olmstead, 2015). These observations suggest that testosterone levels fluctuate rapidly in social interaction, which may subsequently modulate appropriate behavioral changes. In an analogous manner, leading people to engage in motivation-related behavior may modulate the link between hormones and aggression.
The Present Research

In the present study, we examined if avoidance-related behavior may inhibit the relation between high testosterone-low cortisol and increased aggression. We started out by inducing anger among our participants and manipulated body postures associated with approach and avoidance motivation (Harmon-Jones, Gable, & Price, 2011; Harmon-Jones & Peterson, 2009). Prior research has shown that leaning backward reduces approach motivational responses relative to leaning forward (Price & Harmon-Jones, 2011). Consequently, we asked participants in the avoidance condition to lean back, and asked participants in the approach condition to lean forward. In addition, we added a sitting straight condition as a control condition. We measured participants’ aggressive impulses using a validated paradigm (Dewall et al., 2013). Finally, we collected saliva samples at the beginning and the end of the experiment to measure participants’ baseline and reactive levels of testosterone and cortisol.

Our main theoretical prediction was that leaning backward, compared to leaning forward, would inhibit the interaction between testosterone-cortisol levels and aggression. We also expected that the sitting straight condition would differ from the leaning backward condition, but not from the leaning forward condition, given that prior findings suggest that approach motivation is the default response (Price and Harmon-Jones, 2011; Veenstra et al., unpublished results, Chapter 4). Thus, we predicted that the combination of high testosterone-low cortisol would only be associated with increased levels of aggressive impulses after activating approach motivation (leaning forward, or sitting straight), but not after activating avoidance motivation (leaning backward).

Most research investigated the association between baseline levels of testosterone and cortisol and aggression (McBurnett et al., 2000; Popma et al., 2007; Sherman et al., 2016; Yildirim & Derksen, 2012). However, research suggests that hormone reactivity is also associated with aggression, illustrated by the hormone administration (Enter et al., 2014; van Peer et al., 2007; Zak et al., 2009), and hormone responsivity (Carré and Olmstead, 2015; Das and Sawin, 2016; Price et al., 2012) effects on aggression. For this reason we predicted that the effect of motivation on the hormone-aggression link would be present for both baseline and reactive hormone levels.

Method

Participants and Design

This study was carried out in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants, and the Scientific Research Ethics Committee from the Vrije University Amsterdam approved the protocol. One-hundred-ninety-nine healthy participants were included in the experiment. Participants were students (172 women, $M_{age} = 20.44$, $SD_{age} = 3.37$, range = 17-42) from the VU University Amsterdam who received €11.00 (about $12.50) or course credits for their voluntary participation. Exclusion criteria included: extreme high daily activity (top-athletes), insomnia, high nicotine, alcohol or caffeine intake, steroid medications, chronic hormonal diseases, psychopathological, or memory problems. Thirty-three females reported that
they took birth control pills. However, the results reported below did not change when we excluded the latter participants from the analyses. To retain statistical power, we included females on birth control in the results reported below. Participants were asked not to exercise 24 hours prior to the study or consume caffeine or food 1 hour before the study. Participants were randomly assigned to either the leaning forward ($N = 71$), sitting straight ($N = 65$), or leaning backward ($N = 63$) condition. The main dependent variable was participants’ aggression towards a recalled provocative person. Testosterone and cortisol samples were assessed before and after the experimental procedure.

**Sampling Plan**

To determine the number of participants, we ran a G$^*$power (Faul, Erdfelder, Lang, & Buchner, 2007) analysis for ANOVA repeated measures, within-between interaction, to test the within (testosterone: pre vs. post) and between (motivation: approach vs. control vs. avoidance) effects on aggression. Based on our previous studies with motivation and anger (Veenstra et al., unpublished results, Chapter 4) we expected the effect size to be small. Based on an alpha level of .05, a desired power of .80, an effect size of $f = .15$, and an estimated correlation of .4, we determined the required sample size to be $N_{\text{required}} = 132$. We decided to collect data for 65 participants per motivational group (total around 200), to be ensure adequate power to detect the predicted effects.

**Procedure**

Participants started with an intake session. Participants were welcomed by a female experimenter, seated behind a computer screen in separate research cubicles where they read and signed informed consent. Participants started with the general health questionnaire. When participants met the inclusion criteria, they answered several personality questionnaires (individual differences in trait anger, aggression, trait anxiety, behavioral activation and inhibition, and depression). These measures were exploratory and not of interest for the present hypotheses, thus will not be discussed any further. After the questionnaires, participants received instructions and made an appointment for the experimental session.

Because hormone levels stabilize in the afternoon, the experimental session was scheduled between 2 pm and 6 pm. Participants were seated behind a computer in separate research cubicles. They started with a baseline saliva assessment. The remaining experimental instructions were computer-administered. Participants were asked to recall an autobiographical situation in which a person close to them made them angry. Subsequently, we manipulated seating posture by asking participants to lean forward (approach), sit straight (control), or lean backward (avoidance). Afterwards, participants completed measures of aggression using the voodoo-doll task (explained below)\(^6\). Then, participants were then instructed to release the instructed seating position.

\(^6\) After participants completed the voodoo-doll task, we also measured participants’ level of state anger toward the recalled provocative person using 5 self-report items. Further elaboration on the materials and results can be found in the supplemental materials.
and continued to complete the experimental part by answering control questions concerning the manipulation, and reporting demographic information. Participants were then asked to provide a saliva sample once more. Finally, participants were debriefed and rewarded with course credits or money.

Materials and Measures

Hormone assessment. To assess levels of testosterone and cortisol, participants provided two saliva samples of 1.5 ml using vials, i.e., the salicap device (IBL-International, Hamburg, Germany). The time between the anger induction and second assessment was at least 20 minutes and max 30 minutes, given that testosterone and cortisol levels need time to be influenced by psychological processes (Hellhammer, Hubert, & Schurmeyer, 1985).

The saliva samples were frozen and stored at -20 °C until analysis, and shipped on dry ice to the endocrinology laboratory at Technical University Dresden. After having been thawed out, salicaps were centrifuged at 3,000 rpm for 5 min, which resulted in a clear supernatant of low viscosity. Salivary concentrations were measured using commercially available chemiluminescence immunoassays with high sensitivity (IBL-International, Hamburg, Germany). Sample and reagent handling was semi-automated using a liquid handling robot (Genesis, Tecan, Switzerland) and quality control samples of low, medium, and high cortisol or testosterone concentrations were run on each microtiter plate assayed.

The intra and interassay coefficients for cortisol were both below 8% and for testosterone below 10%. To better approximate a normal distribution, we used the log-linear transformation of the data in the analyses reported below. To create a measure of testosterone and cortisol reactivity, baseline assessment was subtracted from post-experiment assessment. Higher levels of the hormonal change scores indicate an increase in hormonal levels, and lower levels indicate a decrease in hormonal levels.

Anger induction. To create an anger-relevant situation, we asked participants to recall a situation in which a person close to them (partner, ex-partner, or best friend in case there is/was no partner) treated them unfairly and made them feel angry. Participants were asked to write about the event for 4 minutes, timed on the computer to prevent them to continue before the time had passed. To bolster the induction, participants were asked to go into detail about the nature of the stressor, how their anger developed, what they thought about the outcome, how it made them feel, and what they did in response to the situation. Participants were not asked about why the event occurred, but about how it occurred, because describing why an event occurred activates people to analyze the event. However, recalling how an event occurred evokes affect, because it causes people to relive the event. Autobiographical recall of emotional situations is an extensively validated procedure to generate negative affect (Westermann, Spies, Stahl, & Hesse, 1996).

Moreover, for exploratory reasons, we also assessed participants’ cardiovascular activity during the experimental session. The relevant data is available on request.
Posture manipulation. After the anger induction, participants’ motivational orientation was manipulated using different body postures (Harmon-Jones et al., 2011). All participants were seated in an office chair with arm- and backrests. To activate an approach orientation, participants were asked to lean forward, such that their upper body was nearer to the computer screen than their hips. Participants were able to lean with their arms on the desk in front of them. The instructions were accompanied by a picture of a person in the leaning forward position (left panel of Figure 1). To activate an avoidance motivational orientation, participants received instructions to lean backward, such that their upper body was further away from the computer screen than their hips. The instructions were accompanied by a picture of a person in the leaning backward position (right panel of Figure 1). Finally, participants in the control condition were asked to sit in a straight position, such that their upper body was straight above their hips, illustrated by the picture of a person in the straight position (middle panel of Figure 1).

Figure 1. Pictures of instructed seating postures to activate motivational orientations. The left panel shows a leaning forward posture to activate an approach motivational orientation, the middle panel shows a sitting straight posture serving as a control condition, and the right panel shows a leaning backward posture to activate an avoidance motivational orientation.

Aggressive impulses – voodoo-doll task. To measure participants’ aggressive impulses, we used the voodoo-doll task (e.g., Dewall et al., 2013). In the voodoo-doll task participants are asked to imagine that a doll represents the person that harmed them, and given the opportunity to insert pins into the doll. Because people assimilate something that is similar to an object with a real object, harming the doll with pins is equivalent to the psychological process of causing harm to the person that the doll represents, and as such represents aggressive impulses (e.g., Dewall et al., 2013). Although the task is developed only recently, it has been validated as measure of aggression and aggressive impulses (Dewall et al., 2013).

During the experiment, a doll and a container of 190 pins lay in a cardboard box on the desk. Participants were asked to get the doll out of the box, and received the following instructions on the computer screen: “The memory you recalled could have caused negative feelings. However, research has shown that you can get rid of this negative energy by taking action in response to a person that caused you harm. You now have the opportunity to put as many pins in the doll at any place you like”. After two minutes, participants could continue by clicking to the next screen. Before they continued
they were instructed to put the doll – including the inserted pins – into the cardboard box again, which made it possible for the experimenter to record the count of pins and a picture of the doll, after the participants were finished. The number of pins was used as a measure of aggression \((M = 10.78; SD = 17.67, range = 0-120)\). Overall, 27.6\% of participants did not insert any pins, 38.2\% inserted 1-10 pins, 29.6\% inserted 11-40 pins, and 4.5\% inserted more than 40 pins into the doll. We used negative binomial regression analysis to analyze the data, to address the problem of overdispersion, i.e., for count data the ratio of the standard deviation to the mean is greater than one (Long, 1997).

**Control measures and manipulation checks.** To check for compliance with the posture instructions, we asked participants a) which seating posture they had adopted (forward, straight, backward), b) whether they had adopted the body posture during the instructed period, c) how comfortable participants experienced the instructed posture \((1 = \text{not at all}, 100 = \text{very much}; M = 46.53; SD = 28.38)\). In addition, as control measures of the voodoo-doll task we asked participants a) whether they put pins in the doll \((\text{yes}, n = 144; \text{or no}, n = 55)\), b) whether participants felt they could get rid of negative energy by putting pins into the doll \((1 = \text{not at all}, 100 = \text{very much}; M = 27.86; SD = 27.06)\), c) whether participants felt they could take revenge to the person that harmed them by putting pins into the doll \((1 = \text{not at all}, 100 = \text{very much}; M = 20.73; SD = 25.22)\).

**Results**

**Manipulation Checks and Missing Data**

**Posture manipulation.** Eight participants reported not sitting in the instructed position, and were excluded from the analyses. Participants leaning forward reported lower levels of comfort \((M = 28.49, SD = 21.32)\) compared to participants leaning backward \((M = 50.05, SD = 28.91), t(100.56)^7 = 4.69, p = < .001, d = 0.81, 95\%CI d [0.45; 1.17],\) or participants sitting straight \((M = 61.52, SD = 20.28), t(123.56) = 8.92, p = < .001, d = 1.53, 95\%CI d [1.14; 1.91].\) In addition, participants leaning backward reported lower levels of comfort than participants sitting straight, \(t(113) = 2.47, p = .015, d = 0.44, 95\%CI d [0.08; 0.79].\) However, when we used participants’ rated comfort as a covariate in the statistical analyses reported below, it did not account for any of the motivational effects on aggression we found in the experiment. Thus, the different levels of comfort connected with the different postures did not appear to have influenced the results. Further details on the latter analyses can be found in the supplemental materials.

**Voodoo doll task.** The behavioral data of three participants were missing, as they reported that they had put pins into the dolls, but no actual pins were found in the doll after they had finished. Presumably, these participants had removed the pins before putting the doll back in the paper box. The data contained two outliers \((118 \text{ and } 120 \text{ number of pins, } > 6 \text{ SD, the model fit improved after exclusion of the outliers}).\) The results of the relevant hypothesized effects without the outliers did not deviate from the

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7 Because the results of a Levene’s test showed that the variances between the groups were unequal, we used the adjusted t-test with adjusted degrees of freedom.
results with the outliers. Nevertheless, we report the results of the analyses excluding the outliers (see supplemental materials for details about alternative analyses).

To check whether the voodoo-doll task tapped into aggressive inclinations, we examined whether the number of pins put into the doll was related to a higher level of self-reported anger measures that were assessed in the experiment. Indeed, a negative binomial regression analysis showed that putting more pins in the doll was related to increased feelings of being able to take revenge on the person that harmed them, $\chi^2(1) = 22.97, p < .0001, \text{Exp}(B) = 1.018$, and to get rid of negative energy, $\chi^2(1) = 72.81, p < .0001, \text{Exp}(B) = 1.029$. In addition, a larger number of pins was related to higher levels of state anger, $\chi^2(1) = 52.37, p < .0001, \text{Exp}(B) = 1.035$. These manipulation checks confirm the validity of the voodoo-doll task.

**Hormone measures.** Four participants had missing hormonal data, due to mislabeling of their saliva samples. Overall, participants’ level of testosterone increased from baseline, $M = 30.30, SD = 32.36$, to post-experiment assessment, $M = 33.59, SD = 39.06$, $t(184) = -2.71, p = .007, d_z = 0.20, 95\%CI [0.05, 0.34]$. There was no significant overall change in participants’ level of cortisol from baseline, $M = 3.50, SD = 2.37$, to post-experiment assessment, $M = 3.30, SD = 2.07$, $t(184) = 1.79, p = .076, d = 0.13, 95\%CI [-0.01, 0.28]$. Male and female participants differed in their pre- and post-levels of testosterone, ($ps < .001$), such that men had higher pre- and higher post- levels of testosterone than women. Because this sex difference increased the heterogeneity of the measurements, and because the overwhelming majority of participants (91%) was female, we report the results of baseline testosterone-cortisol effects without including the data of the males. Testosterone responses did not differ between men and women, neither did any of the cortisol measures. As such, the results of the reactive testosterone-cortisol effects reported below include both sexes. Note however, that the outcome of our hypotheses tests did not change if we did exclude men from the hormone response analyses (see supplemental material for the details about alternative analyses).

**Motivation and Baseline Hormone Levels**

To test whether motivation moderated the relation between baseline hormone levels and aggression, we conducted a negative binomial regression analysis with posture (leaning forward = 1, sitting straight = 0, leaning backward = -1) as between-subjects predictor, and baseline testosterone and cortisol levels as continuous predictors of number of pins inserted in the doll. First, there was a main effect of posture, $\chi^2(1) = 6.39, p = .041$. The comparisons between the posture conditions showed that in the leaning backward condition, $M = 7.34, SD = 15.46$, the average number of pins was lower than in the leaning forward condition, $M = 11.49, SD = 22.02$, $\chi^2(1) = 5.33, p = .021$, but did not differ from the sitting straight condition, $M = 8.82, SD = 18.76$, $\chi^2(1) = 0.05, p = .819$. For the difference between the average number of pins in the leaning forward and sitting straight conditions there was a trend, $\chi^2(1) = 3.42, p = .064$, such that leaning forward resulted in more pins than sitting straight. There were no main effects of baseline testosterone and cortisol, neither were there any two-way interactions ($ps >$
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.342). The predicted three-way interaction between posture, baseline testosterone, and baseline cortisol was not significant, $\chi^2(1) = 2.52, p = .283$.

**Motivation and Hormonal Reactivity**

To test whether posture moderates the relation between hormonal reactivity and aggression, we conducted a negative binomial regression analysis with posture (leaning forward = 1, sitting straight = 0, leaning backward = -1) as between-subjects predictors, and testosterone and cortisol changes as continuous predictors of the number of pins inserted in the doll. First, there was a main effect of testosterone change, $\chi^2(1) = 4.33, p = .038$, which indicated that participants with increases in testosterone inserted more pins into the doll relative to participants with a decrease in testosterone, $Exp(B) = 1.060$. There were no main effects of posture, $\chi^2(1) = 3.71, p = .157$, and cortisol change, $\chi^2(1) = 2.52, p = .112$, $Exp(B) = 0.496$.

Second, there was a significant two-way interaction between posture and cortisol change, $\chi^2(1) = 18.17, p < .001$. Decreases in cortisol were related to more inserted pins in the leaning forward condition, $\chi^2(1) = 18.04, p < .001$, $Exp(B) = 0.496$. In contrast, in the leaning backward condition, there was an opposite trend, $\chi^2(1) = 3.32, p = .068$, such that decreases in cortisol were related to fewer inserted pins, $Exp(B) = 1.390$. There was no relation between cortisol change and number of pins in the control condition, $\chi^2(1) = 0.39, p = .531$, $Exp(B) = 0.886$. There were no two-way interactions between posture and testosterone change, $\chi^2(1) = 4.51, p = .105$, and cortisol- and testosterone change, $\chi^2(1) = 1.57, p = .210$.

Importantly, the predicted three-way interaction between posture, testosterone change, and cortisol change was significant, $\chi^2(1) = 13.06, p = .001$. The regression coefficients of the posture condition comparisons showed that the testosterone by cortisol interaction in leaning forward differed from the testosterone by cortisol interaction in the sitting straight condition, $\chi^2(1) = 13.00, p < .001$. The testosterone by cortisol interaction in the leaning back condition did not differ from the testosterone by cortisol interaction in the leaning forward condition, $\chi^2(1) = 1.61, p = .204$, nor from the sitting straight condition, $\chi^2(1) = 0.09, p = .769$.

To interpret the observed three-way interaction effect, we conducted a series of follow-up analyses for each posture condition. In the leaning forward condition, the interaction between testosterone- and cortisol change was significant, $\chi^2(1) = 11.98, p = .001$, $Exp(B) = 0.600$. As can be seen in Figure 2, in the leaning forward condition, a relative increase in testosterone resulted in more aggression, but only among participants who displayed relative decreases in cortisol, which is in line with the hormone-aggression hypothesis (e.g., Mehta, & Josephs, 2010; Terburg et al., 2009; Montoya et al., 2012). By contrast, the same interaction was not significant in the leaning backward condition, $\chi^2(1) = 2.52, p = .112$, $Exp(B) = 0.786$. Unexpectedly there was a non-significant trend in the opposite direction in the sitting straight condition, $\chi^2(1) = 3.72, p = .054$, $Exp(B) = 1.472$. Specifically, a relative increase in testosterone resulted in less aggression, but only among participants who displayed a relative decrease in cortisol. In sum, in the leaning back and sitting straight condition relatively increases of testosterone and decreases of cortisol did not result in increased levels of aggression.
Figure 2. Visual display of the negative binomial regression effects (Dawson, 2014) of seating posture (from left to right: leaning forward, sitting straight, leaning backward) on the hormone-aggression link.
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Discussion

Prior research has shown that high testosterone levels combined with low cortisol levels predict increased aggression (Montoya et al., 2012; Terburg et al., 2009; van Honk et al., 2010). In the present research, we hypothesized that motivation-related postures might modulate this relation between hormones and aggression. Consistent with this, the present results showed that for reactive hormonal levels, high testosterone and low cortisol was related to increased aggression when people assumed an approach-related posture. However, high testosterone-low cortisol was not associated with increased aggression when people assumed an avoidance-related posture or a control posture in which they sat straight. The predicted effects emerged for hormonal responsivity, but not for resting hormone levels. The modulating effects of behavior may thus be restricted to hormonal changes (Archer, 2006; Carré & Olmstead, 2015; Das & Sawin, 2016).

Unexpectedly, the combination of high testosterone and low cortisol was inversely correlated with aggression (although this reversal was only marginally significant) when participants were sitting in a straight position. We are reluctant to interpret this finding because it was not theoretically predicted. Moreover, in our behavioral research, we have typically found that the effects of sitting straight are similar to the effects of leaning forward (e.g., Veenstra et al., unpublished results, Chapter 4), which is consistent with the notion that psychologically health samples are likely to be somewhat approach-oriented by default. Nevertheless, we may speculate that sitting straight can sometimes activate the behavioral inhibition system, which is activated when both the approach and avoidance systems are jointly activated (McNaughton & Corr, 2014). Conflicts between behavioral inhibition and approach motivation may invoke automatic regulatory processes (Veling, Holland, & van Knippenberg, 2008) which might have triggered additional suppression of aggressive impulses. Future studies are needed to establish whether our findings with regard to the sitting straight condition are robust. Moreover, ambiguities regarding posture may be further resolved by using alternative methods such as direct brain stimulation to induce motivational states (Hortensius, Schutter, & Harmon-Jones, 2012).

The present results point to a bidirectional link between motivational behavior and hormonal responses. This is broadly consistent with social neuroendocrinology theories on human aggression, which suggest that situational contexts related to sexual arousal (Archer, 2006; Das & Sawin, 2016), or competition (Carré & Olmstead, 2015) induce testosterone increases to enhance competitive or aggressive behavior. Thus, hormones may not only regulate behavior, but, conversely, behavior may also regulate hormone levels to adapt the person’s functioning to situational demands. As such, these findings fit with a situated perspective on emotion regulation (Koole & Veenstra, 2015, Chapter 8), which posits that emotional experiences are dependent on situational affordances. The interplay between reactive hormone levels, motivation and aggressive behavior would seem to be a fruitful avenue for future research.

The present research inevitably has limitations. First, participants did not have a habituation period before providing the baseline saliva sample. Although participants were instructed to avoid physical activity beforehand, we cannot rule out that baseline
hormone levels were influenced by differences in activity. Indeed, this confound could explain why the effects of posture emerged for hormonal responsivity, but not for resting hormone levels. Future studies should hence include better controls for physical activity. Second, although excluding female participants on birth control did not change the results, effects of menstrual cycle cannot be ruled out. Third and last, the present study was a lab study and hence did not measure real-life aggression. The behavioral effects on hormones tend to be much larger in the field research than in the laboratory (Geniole, Bird, Ruddick, & Carré, 2016). To increase ecological validity and increase statistical power, future studies should hence try to measure aggression in real-world settings.

Though the present findings remain preliminary, they could have important practical implications. It appears that lowering approach motivation may put the brakes on the volatile reactions of people with high testosterone-low cortisol. Even when people’s endocrine responses predispose them to behave more aggressively, they may be kept from aggressing by merely adjusting their posture. As such, the present findings highlight the promise of investigating the interface of hormones, motivation, and behavior.
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Supplemental Materials

To foster best scientific practices and increase the replicability of our findings, we provide an overview of the materials used in the experiment in the present supplementary materials. Additional data or measures that are not further elaborated can be obtained from the first author upon request.

Method

Procedure. For exploratory reasons, we assessed several personality questionnaires, and measured participants’ level of self-reported level of state anger toward the recalled provocative person. Additionally, participants cardiovascular measures were assessed during the experimental session as well. Five participants have missing heart rate data, due to detaching electrodes during the experiment. During the experimental session participants were attached to the heart rate apparatus after the first saliva sample was collected. The apparatus was disconnected again after the computer tasks, before the second saliva assessment.

State anger. After the voodoo doll task, participants reported on 100-point visual analogue scales (1 = definitely not, 100 = very much) 1) how angry they felt towards the person they had just recalled, 2) how stupid they thought his/her behavior was, and to what extent they were inclined to 3) take revenge, 4) punish, and 5) forgive the person. The five items were averaged into a single measure of state anger ($M = 60.48; SD = 17.79; \text{Cronbach’s } \alpha = .77$).

Control measures. In addition to the control questions reported in the main manuscript we also asked participants to report a) what person they recalled (partner/ex-partner/best friend). Moreover, we checked whether participants indeed restrained from behaviors that could influence the hormone assessment, by asking participants to report b) how many coffee cups they had drunk during the day ($M = 1.33, SD = 0.59$), c) when they had eaten the last time today, d) whether they had smoked more cigarettes than normal during the day (yes, $n = 2$; no, $n = 37$), and their e) handedness (right, $n = 178$; left, $n = 21$).

Results

For the analyses reported below, we applied the same exclusion rules as in the main manuscript, i.e., we excluded participants who reported an incorrect seating posture, or who had missing Voodoo doll task data. In addition, we excluded the two extreme outliers from the aggression data.

Outliers. Analyzing the data of the motivational effects on the baseline hormone-aggression link without excluding the aggression outliers resulted in a trending main effect of motivation ($p = .059$) instead of a significant main effect ($p = .041$). Testing the difference of number of pins between the leaning forward and straight condition resulted in a non-significant effect ($p = .701$) instead of a trend ($p = .064$). The remaining main
and interaction effects of the baseline hormone effects did not differ when we included the outliers.

Analyzing the data of the motivational effects on the reactive hormone-aggression link without excluding the aggression outliers resulted in a significant \( p < .001, \quad \text{Exp(B)} = 0.496 \) instead of non-significant \( p = .112 \) main effect of cortisol change. In contrast, the main effect of testosterone change became non-significant \( p = .676 \) instead of significant \( p = .038 \) when including the outliers. Moreover, the two-way interaction between testosterone and cortisol change was significant \( p < .001 \) instead of non-significant \( p = .210 \). The remaining main and interaction effects of the reactive hormone effects did not differ after including the outliers. Most importantly, the outcome of the three-way interaction between motivation, and testosterone-cortisol change and its follow up analyses did not change either.

**Gender.** When we included males in the analyses of the baseline hormone effects, the main effect of motivation became a trend \( p = .082 \) instead of significant \( p = .041 \). The comparisons between the motivation conditions yielded a non-significant difference in number of pins between the leaning forward and sitting straight condition \( p = .519 \) instead of a trend \( p = .064 \). Similar to the results without males, there were no main effects of baseline testosterone and cortisol, neither were there any two-way interactions. The predicted three-way interaction between motivation, and testosterone-cortisol baseline became a trend \( p = .068 \) instead of non-significant \( p = .283 \). However, none of the testosterone-cortisol interactions differed between the posture conditions (all \( p's > .085 \)).

When we excluded males in the analyses of the reactive hormone effects, the outcome of the predicted three-way interaction and follow up analyses yielded no different outcomes than the results reported in the manuscript. However, the main effect of cortisol change became significant \( p = .012 \) instead of non-significant \( p = .112 \), and the main effect of motivation became a trend \( p = .072 \) instead of non-significant \( p = .157 \). The main effect of testosterone was still significant \( p = .022 \). Moreover, two-way interactions between motivation and testosterone change became a trend \( p = .062 \) instead of non-significant \( p = .105 \), as did the two-way interaction between cortisol and testosterone \( p = .055 \) instead of \( p = .210 \). The two-way interaction between motivation and cortisol did no change \( p < .001 \).

**Level of comfort.** Because we found differences in comfort between the motivation conditions, we also included level of comfort into the model, as covariate or as moderator, to test whether the motivational effects on aggression were explained by levels of comfort. Level of comfort was not a significant covariate when included in the model with motivation, testosterone, and cortisol (baseline or response). Moreover, the effect of seating posture on the hormone-aggression link was not moderated by the level of comfort (no four-way interaction between level of comfort X posture X testosterone X cortisol, baseline or response). In sum, the results showed that level of comfort did not account for the reported effects of motivation and hormones on number of pins.

Because we found differences in comfort between the motivation conditions, we also explored whether the level of comfort moderated the effect of seating posture on aggression. We conducted a negative binomial regression analysis with seating posture
(forward, straight, backward), level of comfort, and their interaction as predictors of number of pins. First, the results showed that higher levels of comfort predicted a smaller number of pins, $\chi^2 (1) = 4.93$, $p = .026$, $Exp(B) = 0.985$. Second, the main effect of seating posture on aggression was significant, $\chi^2 (2) = 8.42$, $p = .015$. The pattern of results was similar to the effects of motivation on aggression in the main manuscript, such that participants put more pins into the doll in the leaning forward and sitting straight condition, than in the leaning backward condition.

In addition, level of comfort interacted with body posture, $\chi^2 (2) = 13.92$, $p = .001$. The leaning backward condition did not differ from the leaning forward condition, $\chi^2 (1) = 0.018$, $p = .983$, in both the leaning backward ($\chi^2 (1) = 8.57$, $p = .003$, $Exp(B) = 0.985$) and sitting straight condition ($\chi^2 (1) = 6.02$, $p = .014$, $Exp(B) = 0.984$), higher levels of comfort were related to a smaller number of pins. However, the leaning forward condition differed from both the leaning back, $\chi^2 (1) = 10.95$, $p = .001$, $Exp(B) = 1.025$, and sitting straight condition, $\chi^2 (1) = 9.12$, $p = .003$, $Exp(B) = 0.975$, such there was a trending positive relation between comfort and number of pins ($\chi^2 (1) = 3.12$, $p = .077$, $Exp(B) = 1.009$). To conclude, the results suggest that higher levels of discomfort in the approach condition caused more aggression, however, higher levels of comfort decreased aggression in the control and avoidance conditions. Importantly, we did not find evidence that this affected the motivation interaction with hormones on aggression.

State anger.

Motivation and baseline hormone levels. We conducted an ANCOVA with posture (leaning forward vs. sitting straight vs. leaning backward) as between-subjects factor, and baseline level of testosterone and cortisol as continuous predictors of state anger. Similar to the results of the baseline hormone effects in the main manuscript, we excluded males from the analyses. If we included males in the analyses, there were no main and interaction effects at all.

First, the main and two-way interaction effects showed that there was a significant main effect of baseline testosterone, $F(1, 152) = 7.02$, $p = .009$, $\eta_p^2 = .044$, such that higher levels of state anger was related to higher levels of baseline testosterone, $r = .16$. The three-way interaction between posture, and baseline level of testosterone and cortisol was not significant by conventional standards, $F(1, 152) = 2.45$, $p = .066$, $\eta_p^2 = .046$. For exploratory reasons, we conducted follow-up analyses to determine the nature of this interaction effect. In the control condition, there was an interaction between baseline testosterone and baseline cortisol, $F(1, 45) = 7.07$, $p = .011$, $\eta_p^2 = .136$, such that when cortisol levels were low, testosterone predicted more state anger, but not when cortisol levels were high. Moreover, the effect of hormones on anger seemed to be most pronounced when anger levels were low, such that low testosterone predicted less anger when cortisol was low as well, as visualized in Figure 1. There were no significant effects of baseline testosterone and cortisol in the forward- and backward-leaning posture conditions. However, we should be cautious with interpreting these results, given that the interaction was not significant.
Motivation and the hormone-aggression link

Figure 1. Effect of motivation and baseline hormone levels on state anger.
**Motivation and hormonal reactivity.** We conducted a 3 way (posture: leaning forward vs. sitting straight vs. leaning backward) ANCOVA with testosterone and cortisol change in the model as continuous predictors, and state anger as dependent variable, including both men and women. We found a main effect of testosterone change on state anger, \( F(1, 179) = 4.71, p = .031, \eta^2_p = .026 \), such that an increase in testosterone was related to less state anger, \( r = -.19, p = .009 \). The three-way interaction between motivation and testosterone and cortisol change was not significant, \( F(3, 179) = 1.35, p = .259, \eta^2_p = .022 \), neither were any of the remaining main and two-way interaction effects.