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Cortisol and Testosterone in Leadership Practice

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Abstract: This study sought to discover whether and how biological parameters can predict leadership behavior in the following leadership-related tasks: a face-to-face negotiation (Study 1), an individual problem-solving case (Study 2), and a group-based problem-solving case (Study 3). We replicated previous work by Mehta, Mor, Yap and Prasad in testing the dual-hormone hypothesis related to testosterone increase and cortisol decrease (Study 1), but our findings do not provide evidence to support the dual-hormone hypothesis. In Study 2, we found that high openness was a significant predictor in the individual problem-solving case. The results from Study 3 indicated that higher openness was related to a better score on the group exercise. Our findings did not support the dual-hormone model, and we did not find support for the seller-specific effect reported in Mehta et al. The original study included 64 participants with complete hormone data, while our replicational study involved 114 participants with complete hormone data.

Keywords: testosterone; cortisol; leadership; negotiation; decision making

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1. Introduction

Can biological markers provide new perspectives on leadership performance? How can biological parameters predict leadership behavior in various leadership-related tasks? In leadership research, there is an increasing awareness of the need to integrate knowledge from the natural, biological, and social sciences in order to find new and more adequate explanations for leadership [1–3]. Researchers have sought to explain leadership as a function of individual traits and charisma, and through follower-centric approaches and theories emphasizing relational factors, as well as contextual and situational perspectives, in addition to theories emphasizing shared leadership [4].

Historically, there have been contributors within the psychological and sociological fields who have answered this question, but in recent years, a wave of biological explanations has emerged, which rely on hormone studies and, for example, the endocrinological profile of a leader. In addition, there are explanations based on evolutionary psychology, twin studies, and brain scanning; however, little has been proven.

Laboratory experiments have nevertheless shown that high testosterone individuals tend to exhibit better performance on cognitive tasks when appointed to leadership roles. In contract, individuals with low testosterone tend to perform better in roles characterized by followership [5].

Testosterone has also been positively associated with attained status—the number of subordinates over which an executive has authority—but only for low-cortisol leaders [6]. More specifically, it is argued that high-testosterone, low-cortisol leaders are particularly likely to occupy high-status positions, whereas low-testosterone, low-cortisol executives are likely to occupy low-status positions. It has thus been claimed that high testosterone coupled with low cortisol may be a hallmark of powerful individuals [7] and thus associated with leadership, at least for male leaders. The findings also support claims that

testosterone's link to status and social dominance is conditioned by other factors, especially cortisol [8]. Additionally, experiments have shown that cortisol and testosterone changes are associated with bargaining outcomes, which are also relevant to leadership situations. In competitive negotiations and bargaining games, testosterone increases have been linked to higher earnings, and better quality in relationships, but only when a decrease in cortisol is present [9]. Incompatibility between financial goals and social dominance is associated with the financially costly dual-hormone profile. In contrary, a financially adaptive dual-hormone profile is associated with an absence of this incompatibility.

2. The Dual-Hormone Hypothesis

Mehta and Josephs [10] proposed the dual-hormone hypothesis, predicting that testosterone should interact with cortisol such that testosterone should be positively correlated with status-seeking behavior only when cortisol concentrations are low. Their findings suggested that only when cortisol is low does higher testosterone encourage status-seeking behavior. When cortisol is high, a high level of testosterone may actually decrease the behavior associated with dominance and, in turn, motivate the acceptance of a lower status [10,11].

Leadership embraces a variety of situations and tasks, and we wanted to explain the significance of biological factors across contexts such as bargaining performance, individual problem solving, and group-based problem solving. We tested the dual-hormone hypothesis by replicating the study of Mehta et al. [9] to determine whether dual-hormone changes are related to bargaining performance (Study 1). In Study 2, we wanted to explore whether and how biological parameters could predict leadership behavior in an individual problem-solving case. In Study 3, the leaders performed a group-based problem-solving case.

In this study, our contribution to the development of the dual-hormone hypothesis is (1) replicating the study of Mehta et al. [9] (Study 1), (2) testing the extent to which hormone levels and interactions (testosterone and cortisol) are capable of predicting *individual* problem-solving ability (Study 2), and (3) testing the extent to which hormone levels and interactions (testosterone and cortisol) are capable of predicting *group efficiency* in problem solving (Study 3).

3. Method

3.1. Participants

Our sample consisted of 114 managers who participated in the study on a voluntary basis. The study meets all relevant ethical guidelines, including adherence to the legal requirements in Norway (REK and NSD). The participants were recruited from a number of MBA programs in Norway designed for senior-level executive officials, including directors, partners, and mid-level managers. Our sample consisted of part-time MBA students where a majority of these held mid-level or senior management positions in their working life. The final dataset included 61 women (ages 27–68 years; M = 43.6 years, SD = 8.4 years). We only have age data for 49 of the women and 53 men (ages 26–58 years; M = 40.6 years, SD = 8.0 years). Each study participant signed a consent form and was able to withdraw from the study at any time. The collected data were tied to participant ID numbers, and the key connecting the participants to their ID numbers was stored separately.

3.2. Personality Questionnaire and Intelligence Test

The participants performed the BOMAT ability test and NEO PI-3 personality test (n = 30 from the study population of 114 took the tests). The revised NEO Personality Inventory (NEO-PI-3) includes 240 items corresponding to the Big Five personality traits [12,13]. The BOMAT is a nonverbal psychometric test constructed to measure fluid intelligence [14,15]. The concept of general cognitive ability is related to important life outcomes, such as work performance [16,17].

3.3. Saliva Collection and Hormone Analysis

The participants were instructed not to eat, drink, smoke, or chew tobacco during the experiment. To collect salivary hormones, the procedures described in Stanton and Schultheiss [18] were followed. For each saliva collection, we collected 2–2.5 mL from each participant into sterile polypropylene microtubules. The saliva samples were immediately placed on ice before subsequent storage in a freezer (−20 °C) within 4–6 h to avoid hormone degradation. Experimental sessions were conducted between 13:00 and 15:00 to minimize the effects of circadian fluctuations in testosterone and cortisol levels [19]. Saliva samples (n = 114) were thawed and analyzed for cortisol and testosterone using HS Salivary Cortisol EIA and Salivary Testosterone EIA assays (Salimetrics, Carlsbad, CA, USA) according to the manufacturer's instructions. Saliva was collected at 3 timepoints during Study 1–3, and the changes in cortisol and testosterone from timepoints 1–2 and 2–3 were calculated.

3.4. Statistics

A hierarchical multiple regression analysis was performed in SPSS (Version 26). A relative weights analysis (RWA) was performed in R (Version 3.6.1) [20] using scripts from RWA-WEB [21]. The Pearson correlation was analyzed in R. Plots were generated using ggplot2 [22] in R.

4. Study 1: Competitive Negotiations Case

4.1. Procedure Study 1

The Synertech–Dosagen [23] negotiation case was used, and the participants were either assigned to the role as a buyer or seller through a randomized process. The case involves bidding for a pharmaceutical plant. To complete the assigned task, participants were asked to read through a description for each role, and the first saliva sample was collected before the negotiation case. The same general information was given to both the buyer and the seller. Both negotiators were told that the plant for sale was located in an area with an experienced but highly mobile workforce and that the neighborhood contained many startup biotechnology firms. The participants were told that the seller had purchased the plant 3 years ago for $15 million. This was considered to be below market value because 2 years ago, the plant was appraised at $19 million, and due to this, the company from which the seller had purchased the plant was in bankruptcy. The study participants were further told that the local real estate market had declined 5% since that time but that the factory was a unique property, and therefore, general trends in property prices could not necessarily be taken into account when calculating the property value. Both negotiators were finally told that a similar factory, only newer, was sold for $26 million 9 months ago [23].

Immediately after the negotiation case, the negotiators were asked to fill out a questionnaire which contained questions about the final negotiation outcome, a measure of the participants satisfaction with the final price, and the apparent quality of their relationship with their negotiation partner [9]. After filling out the questionnaire, a second saliva sample was collected.

4.2. Results Study 1: Dual-Hormone Profiles and Financial Earnings

In Mehta [9], it was argued that simultaneous change in testosterone and cortisol should be associated with higher earnings. It was assumed that testosterone increase would be associated with a higher profit, given that cortisol simultaneously decreased. It was further proposed that higher testosterone levels should be associated with a smaller profit if cortisol levels increased at the same time. The negotiation outcome (final price) was regressed onto the seller and buyer hormone-change variables using hierarchical multiple regression. Cortisol and testosterone change were added to the model in the first step. The interaction term (testosterone change × cortisol change) was added in the second step. Finally, age and gender variables were added as a third step (Model 1).

There were no statistically significant effects on negotiation outcome (final price) on the part of testosterone change ($p = 0.538$), cortisol change ($p = 0.285$), or testosterone change × cortisol change interaction ($p = 0.561$) for buyers ($n = 53$). Adjustment for age, gender, and income did not influence the outcome. There were also no significant effects on the part of changes in hormone levels or interaction for sellers ($p > 0.383$) ($n = 57$). Adjustment for age, gender, and income did not influence the outcomes. The findings from our study did not support the dual-hormone model, and we did not find support for the seller-specific effect reported in Mehta [9]. Our results indicate that overall, earnings were not related to testosterone and cortisol changes.

To further explore dual-hormone interaction, Mehta [9] conducted a simple slopes analysis [24]. To further explore the predicted effects, we conducted a relative weights analysis (RWA) (https://relativeimportance.davidson.edu/, accessed on 9 September 2020) with final price as the dependent variable and gender, age, testosterone change, cortisol change, and testosterone change × cortisol change interaction as predictor variables. No statistically significant weights were found for the variables in the model.

4.3. Study 2: Individual Problem-Solving Case

4.3.1. Procedure Study 2

After finishing Study 1, all participants were instructed to read the instructions for the individual problem-solving case called "Lost at Sea" [25]. To conduct the exercise, the participants were presented with a scenario in which a ship of 10 passengers is about to sink.

4.3.2. The Case

The ship has suffered major damage due to a fire, and most of the equipment onboard has been damaged or lost, including navigation aids. The main objective for each participant is to rank 15 items in order of importance. Officers of the United States Merchant Marines provided the "correct" solution to the task [25].

After 30 min, the facilitator collects the individual worksheets and calculates the individual scores. The score is the sum of the differences between the "correct" rank for each item and its rank on the individual worksheet (all differences were made positive and added). Higher scores have more negative implications.

4.4. Results of Study 2: Individual Outcome of "Lost at Sea"

According to the dual-hormone model proposed by Mehta et al. [9], an increase in testosterone during an individual exercise should be related to increased individual performance if cortisol levels simultaneously decreased, but a rise in testosterone should be associated with decreased individual performance if cortisol levels increased. Using hierarchical multiple regression, the individual exercise score was regressed using Model 1 for all participants ($n = 114$). No significant effects were found in Step 1 (adjusted $R^2 = 0.066$). In Step 2, there were no significant effects on the part of testosterone change ($p = 0.339$) or the testosterone change × cortisol change interaction ($p = 0.191$). However, a cortisol increase was related to lower individual performance, along with an increase in the exercise score (adjusted $R^2 = 0.072$, b = 0.258, 95% CI = [0.005, 0.153], t = 2.130, $p = 0.035$). After adjusting for age and gender, no effect was found on the part of cortisol change. However, both age and gender significantly affected the individual score (adjusted $R^2 = 0.166$). An increase in age was related to a reduction in the exercise score (increased performance) (b = −0.257, 95% CI = [−0.657, −0.070], t = −2.464, $p = 0.016$). Regarding gender, male participants had a decreased exercise score (increased performance) as compared to females (b = −0.238, 95% CI = [−10.592, −0.613], t = −2.236, $p = 0.028$) (Figure 1A). The findings from Study 2 did not support the dual-hormone profile.

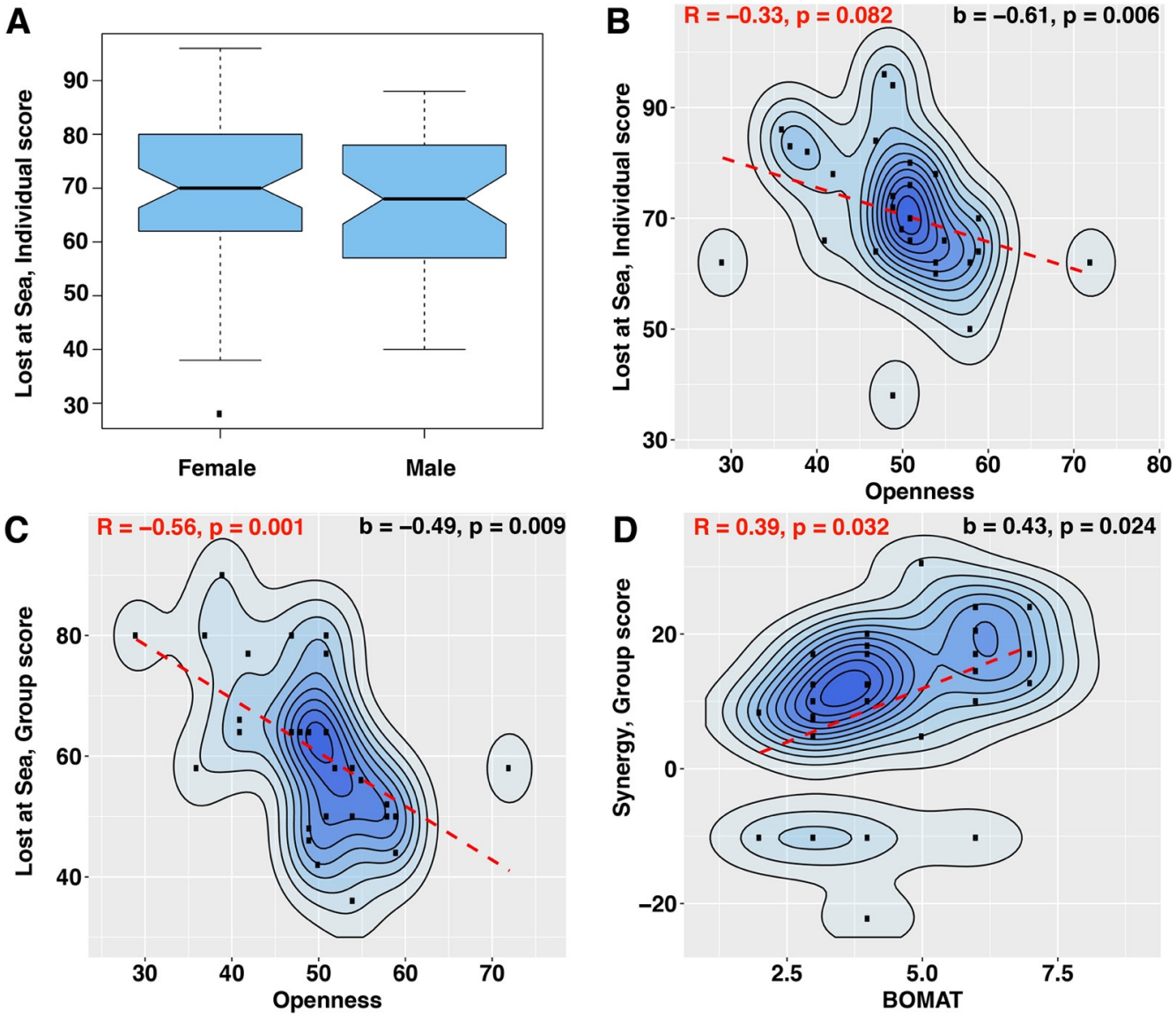

Figure 1. (**A**) Boxplot showing that the individual score for the "Lost at Sea" test is slightly lower (better) for male participants (n = 110). (**B**–**D**) Scatterplots with density scales (dark blue = higher point density), Pearson correlation coefficients with corresponding p-value (red), a dotted line (red) for correlation, and the b-value and p-value from the hierarchical regression (black) (n = 30). (**B**) The Individual score of the "Lost at Sea" test decreases (better performance) with increased openness. (**C**) The group score of "Lost at Sea" decreases (better performance) with increased openness. (**D**) The improvement in group score from the average individual score increases with an increasing BOMAT score.

The hierarchical regression model, Model 1, was adjusted to include BOMAT and the Big Five (Step 3) (Model 2, n = 30), with age and gender being added in Step 4. In Step 1, there were no significant effects on the part of cortisol change, while an increase in testosterone change was related to an increase in exercise score and poorer individual performance (adjusted R^2 = 0.158, b = 0.662, 95% CI = [0.056, 0.746], t = 2.403, p = 0.025). In Step 2, there were no significant effects on the part of cortisol change or the cortisol change × testosterone change interaction, while the effect of testosterone change was retained (adjusted R^2 = 0.168, b = 0.691, 95% CI = [0.074, 0.765], t = 2.515, p = 0.020). In Step 3, the addition of BOMAT and the Big Five to the model resulted in an increased fit (adjusted R^2 = 0.357). An increase in testosterone change was related to an increase in individual exercise score and poorer individual performance (b = 0.748, 95% CI = [0.115, 0.792], t = 2.843, p = 0.012). Increased openness was related to a decrease in the exercise

score (better performance) (b = −0.607, 95% CI = [−1.535, −0.310], t = −3.195, $p = 0.006$) (Figure 1B). Adjustment for age and gender did not affect the outcome for openness, but the outcome for testosterone change was removed ($p = 0.066$) (adjusted $R^2 = 0.267$). The results indicate that an increase in testosterone contributed to lower individual performance on the individual exercise and that an increase in openness was related to better individual performance. No support was found for the dual-hormone model in Study 2.

4.5. Study 3: Group Problem-Solving Case

Procedure: Study 3

After finishing Study 2, all participants were divided into groups and instructed to solve the "Lost at Sea" case [25] as a group. After finishing the group case, a second questionnaire was filled out, and after that, a third saliva sample was collected.

4.6. Results: Study 3

Group Outcome of "Lost at Sea"

In Studies 1 and 2, no support was found for the dual-hormone hypothesis. In order to investigate the effect of hormone changes on the group outcome of the group exercise, hierarchical multiple regression was conducted in which the group outcome of the group exercise was regressed using Model 1 ($n = 114$). In Step 1, there was no significant effect on the part of testosterone change ($p = 0.983$), but an increase in individual cortisol level was related to an increased group exercise score (lower performance) (adjusted $R^2 = 0.081$, b = 0.102, 95% CI = [0.029, 0.175], t = 2.755, $p = 0.007$). In Step 2, there were no significant effects on the part of testosterone change ($p = 0.988$) or the testosterone change × cortisol change interaction ($p = 0.390$). However, cortisol increase had the same effect as in Step 1, though the model explained less of the variation in the dataset (adjusted $R^2 = 0.079$). After adjusting for age and gender, no effect was found on the part of cortisol change (adjusted $R^2 = 0.051$). These analyses indicated that neither cortisol change nor testosterone change affected the group outcomes for the group exercise.

The group score was regressed with Model 2. In Steps 1 and 2, there were no significant effects on the part cortisol change, testosterone change, or the interactions (adjusted $R^2 < 0.15$ for all steps), and gender and age correction did not affect the results. In Step 3, the addition of BOMAT and the Big Five to the model resulted in increased model fit, and increased openness was related to a decrease in group exercise score (adjusted $R^2 = 0.134$, b = −0.477, 95% CI = [−1.597, −0.59], t = −2.262, $p = 0.036$). None of the other parameters was related to the group exercise score in this model. This effect was retained after adding gender and age to the model. These analyses indicated that a higher score for openness was related to a better score on the group exercise.

As cortisol change was related to the group outcome score in the initial analysis, we tested a regression model containing only cortisol change and openness. In this model, there was no significant effect on the part of cortisol change, but increased openness was related to a reduced group outcome score (adjusted $R^2 = 0.213$, b = −0.487, 95% CI = [−1.466, −0.228], t = −2.818, $p = 0.009$) (Figure 1C). Age and gender did not affect this result. These analyses further support the previous results, which indicated that openness predicted performance on the group exercise, but no effect was found on the part of cortisol change. The effect of openness on the group exercise score is a unique finding that merits further investigation.

5. Change from Individual Score to Group Score

The change from the average individual score within the group members to the group score was calculated (synergy score). In order to investigate the effect of hormone changes on the synergy score, the synergy score was regressed using Model 1 ($n = 114$) and using Model 2 ($n = 30$). We did not find any effects on the part of the hormones or hormones and BOMAT/the Big Five together, but BOMAT alone did have an effect. Adding BOMAT and the Big Five personality traits to the hormone model did not reveal any significant effects.

However, if we regress only BOMAT (Step 1) and the Big Five onto the synergy score (adjusted $R^2 = 0.302$), an increased BOMAT score was related to an increase in synergy score (b = 0.429, 95% CI = [0.492, 6.449], t = 2.410, $p = 0.024$) (Figure 1D). In addition, an increase in openness was related to an increased synergy score (b = 0.454, 95% CI = [0.018, 1.091], t = 2.139, $p = 0.043$). There were no effects on the part of the other Big Five parameters. Correction for age and gender resulted in BOMAT ($p = 0.038$) being the only statistically significant parameter (openness, $p = 0.058$), but the model fit was reduced (adjusted $R^2 = 0.254$).

These findings indicate that hormone changes did not affect the difference between individual score and group score. The results further support our previous assumptions that hormones do not play a significant role in understanding group behavior and performance. However, BOMAT may play a role in how a group performs as compared to individual performance.

6. General Discussion

There is a growing interest in biological explanations in psychology today. This study sought to discover how biological parameters could predict leadership behavior in the following leadership-related tasks: a face-to-face negotiation (Study 1), an individual problem-solving case (Study 2), and a group-based problem-solving case (Study 3).

We replicated previous work [9] in testing the dual-hormone hypothesis related to testosterone increase and cortisol decrease (Study 1). In accordance with their findings, our hypothesis was that an increase in testosterone during negotiation would be related to higher overall earnings if cortisol simultaneously decreased, but that an increase in testosterone would be associated with lower earnings if cortisol levels rose (the dual-hormone model). The findings of our study did not support the dual-hormone model, and we did not find support for the seller-specific effect reported in Mehta [9]. Our results indicated that neither the seller's nor the buyer's hormone profiles were associated with stronger overall earnings.

In Study 2, we investigated the dual hormone profile and individual outcomes of the group exercise "Lost at Sea." The findings of our study did not support the dual-hormone profile with regard to individual performance; however, in line with what was predicted in Mehta [9], an increase in cortisol led to poorer individual performance during the group exercise. This effect is lost when adjusting for age and gender. In addition, we found support for the personality trait of openness as a valid predictor of performance in the group exercise. We consider this finding as a very interesting research contribution.

In Study 3, we found that an increase in cortisol had a minor negative effect on the group outcome of the group exercise; however, the effect was not retained after controlling for age and gender. Our subset analysis indicated that a higher openness was related to a better score on the group exercise. Our findings indicate that hormone changes did not affect the difference between individual score and group score. The results further support our previous assumptions that hormones do not play a significant role in understanding decision-making behavior and performance in a group exercise.

A failure to replicate a research result does not necessarily imply that the original study reported false-positive results or conclusions. Differences in empirical or statistical replicational methodology, research samples, or cultural context may interfere with observing the effect [26]. To minimize a priori reasons to expect different results, we used the original standard negotiation case, called the Synertech–Dosagen [23] enrolled participants from an MBA course on a voluntary basis (just as in the original study), and corresponded with the lead author of the original study to ensure that the same statistical procedures were followed. The original study included 64 participants with complete hormone data, while our replicational study involved 114 participants with complete hormone data.

Our results can be seen in the light of previous research findings. In a study by van der Meij, Schaveling, and van Vugt [27], no significant relationship between testosterone and leadership styles was found among participants who currently held a real management

position (they had at least one subordinate). The meta-analysis conducted by van der Meij, Schaveling, and van Vugt [27], showed that basal testosterone was associated with neither having a leadership position in the corporate world or to leadership style among leaders. The support for the dual-hormone hypothesis could be perceived as wide ranging, but insignificant findings and theoretical ambiguity must be taken into account [28].

According to Sapolsky [29], high testosterone concentrations do not promote aggression but, rather, whatever behaviors are needed to maintain status. One potential interpretation of our results is that dominance, in a leadership context, is not associated with high testosterone concentrations but, rather, that testosterone primarily promotes the behavior necessary to maintain status. Dominance is part of our primal heritage, and there is always a risk that leaders will force subordinates into submission [30,31] or exercise forms of destructive leadership in other ways [32,33]. Furthermore, dominance is often taken as competence [34]. However, leadership theory development is, in general, moving toward postheroic approaches to leadership, as well as more relational, processual, and followership-centered leader–follower relations. Testosterone may therefore not be the key to asserting leadership abilities. Even more problematic is the downside of leader dominance and status positioning. Psychological studies report correlations between leadership and such traits as assertiveness, boldness, initiative, the need for achievement, proactivity, and risk taking [35,36]—all such traits increase the likelihood of being the first to act due to dominance strategies [37].

Individuals with a strong will to power are inclined to seek positions of authority [38], and studies show a relationship between a desire for power and advancement to leadership positions [39]. However, the same forces that lead leaders to seek responsibility may also be destructive. Qualities that may be important for individuals to become leaders and may facilitate the exercise of successful leadership may also contain elements of psychoticism [40]. This concerns traits such as aggression, egocentrism, antisocialism, and narcissism [41], and even sadistic traits [42]. Power positions also seem to appeal to individuals with self-centred, status-obsessed, emotionally cold, and aggressive personalities. Research has shown that such personality types are disproportionately represented in executive positions [43]. Studies also show that people who have power are quicker than others to bend moral boundaries, give themselves benefits, exercise double standards, and demand more of others than they do of themselves [44]. Additionally, people in positions of power often feel that they control more than they actually do, and they overestimate themselves and their actions [45]. We suggest that the distinction between dominance and leadership should be further explored in empirical studies of testosterone.

The dual-hormone hypothesis, as proposed by Mehta et al. [9], is not supported by any of the three studies. Our results may suggest that the personality trait of openness could be a significant predictor of effective leadership behavior in terms of handling complex, new, and challenging problems. In a knowledge-based organizational context, effectiveness in individual- and group-based problem solving is crucial for successful leadership.

A biological understanding of human behavior can provide an increase in predictive power, offer comparative perspectives, and suggest new understandings and interpretations of human behavior. Some of what is claimed today is still too unexplored to be conclusive. We must have patience and criticize, challenge, and test new knowledge before we consider it to represent scientific truth.

In order to achieve acceptable statistical power, sample size is crucial. This is especially critical in estimating interactional effects and creates difficulties interpreting the research findings in the dual-hormone literature. Gelman [46] claims that 16 times the sample size is needed to estimate an interaction effect as compared to a main effect. Several of the studies of dual-hormone changes have a modest sample size, including Mehta et al. [9] which consisted of 70 participants, while the sample size in our study is 114 and constitutes a significant limitation.

Improved methods (for example, multimethods, method triangulation, and time studies) are required, and we must challenge established scientific "truths", as well as new

research results. We hope future research will explore our findings indicating that higher openness is related to a better score on group exercises. Future studies should critically examine whether systematic fluctuations in endocrinological data can be generalized across other organizational contexts, such as the army, knowledge-based organizations, the police, healthcare, and politics, as well as across other cultures and countries.

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