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# Testosterone as a Social Inhibitor: Two Case Studies of the Effect of Testosterone Treatment on Language

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This study aimed to correlate testosterone levels with natural written language in 2 people undergoing testosterone therapy. Two participants, a man receiving treatment for loss of upper-body strength and a female-to-male transgendered individual, supplied records of injections over 1–2 years along with e-mails or journal entries as writing samples. Results showed that higher testosterone levels correlated with reduced use of words related to social connections. Language relating to anger, sexuality, and achievement was unrelated to testosterone levels. It appears that testosterone steers attention away from social connections but not necessarily toward concerns with aggression or sexual activity.

Language is inherently social. It is not surprising, then, that the ways in which people select and use words in everyday life correlate with their social and psychological states, moods, depression levels, and health. Subtle fluctuations in linguistic style can signal changes in people's social worlds. Endocrine systems are also related to social factors, guiding social, sexual, and aggressive behaviors. This raises the question: Do fluctuations in hormone levels, such as testosterone, correlate with changes in word use?

Of all the hormones, testosterone is one that is routinely linked with social behaviors. Testosterone levels represent one of the biggest hormonal differences between men and women (Christiansen, 1998). As a result, laypeople and scientists alike often hold this particular hormone responsible for many of the differences between men and women, differences between men of the same age, and behavioral changes within one person over different points in life (e.g., adolescence relative to middle age). Many studies have linked testosterone with aggression (an effect size of $d = 0.40$ was reported in a meta-analysis by Archer, Birring, & Wu, 1998). Testosterone has also been linked to negative moods (Doering, Brodie, Kraemer, Becker, & Hamburg, 1974), sex drive (Schiavi, White, Mandeli, & Levine, 1997), and even improved spatial skills and impaired verbal ability (Christiansen & Knussmann, 1987; but see also contrasting findings by O'Connor, Archer, Hair, & Wu, 2001). High levels of testosterone are related to concerns over status and dominance (Josephs, Newman, Brown, & Beer, 2003). Other researchers have argued that testosterone promotes "simple thought and action" (Dabbs & Dabbs, 2000, p. 43), paying less attention to abstract, subtle, or complex objects and relationships. Men with high testosterone levels are less likely to marry, are more likely to divorce, and report a lower quality of marital interaction (Booth & Dabbs, 1993).

A difficulty in human testosterone studies has been tracking naturalistic, long-term changes that are not biased by participants' beliefs. A promising solution that goes beyond self-report measures is to track the ways in which individuals use language. In recent years, several labs have found that the ways people use words in written text reveal a great deal about their psychological states. Analyses of linguistic style as opposed to linguistic content have been especially successful, particularly analyses of function words (also known as particles): pronouns, articles, prepositions, conjunctions, and auxiliary verbs.

Using a simple text analysis program, researchers have linked the use of particles to suicide proneness (Stirman & Pennebaker, 2001), personality and health-seeking behavior (Pennebaker & King, 1999), age (Pennebaker & Stone, 2003), and authors' sex (Groom, Stone, Newman, & Pennebaker, 2003). This program, Linguistic Inquiry and Word Count (LIWC; Pennebaker, Francis, & Booth, 2001), processes electronic text files to yield the percentage of words in each file that fall into each of 74 predefined word categories. Categories range from emotion-related words to prepositions. Except for purely linguistic categories, human raters were used to decide whether a particular word belonged in categories such as *optimism*, *anger*, and so on. In this way, an element of human qualitative judgment is built into an otherwise automated procedure. Projects using other language analysis techniques have linked linguistic style to mood, aggression, sexuality, achievement, cognitive complexity, and other dimensions (Pennebaker et al., 2001; Pennebaker, Mehl, & Niederhoffer, 2003).

In the present study, we tracked the language use of two individuals who were receiving testosterone injections for different reasons. Both individuals provided a record of their injections and extensive writing samples for 1–2 years prior to the study. Prior to receiving feedback about their results, both individuals were queried about their beliefs concerning testosterone's role in influencing language. On the basis of the dimensions of language examined, we were able to test whether testosterone changes over time

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correlated with various dimensions of language use often thought to be related to testosterone. In particular, we tested the commonly held expectations that testosterone would be related to six psychological domains: (a) aggression, dominance, and sexual behavior; (b) spatial thinking; (c) less complex thinking; (d) greater action orientation; and (e) more positive emotions. In addition, on the basis of the idea that high testosterone levels may be associated with less rich relationships with others, we looked for evidence of fewer references to social connections.

## Method

### *Participants*

*Case 1.* D.M., a 60-year-old married, heterosexual, biological man, began testosterone injections at the age of 56 on the advice of his physician to restore his gradually deteriorating upper-body strength. According to his detailed records, D.M. self-injected 1 cc of testosterone cypionate (Depo-Testosterone, Pharmacia & Upjohn Company, Kalamazoo, MI) at a concentration of 200 mg/ml approximately every 3 weeks (10–28 days). D.M. volunteered for the study after a chance meeting with James W. Pennebaker in 2002. He supplied all of the treatment records from January 2000 to January 2001, together with his entire outgoing e-mail files for that period.

*Case 2.* G.H., a 28-year-old unmarried biological woman, began testosterone treatment at the age of 25 as part of a transgender procedure to become a male. A double mastectomy was the only surgical procedure that had been undertaken, but G.H.'s coworkers believed him to be a biological man. Treatment took the form of 200 mg/ml testosterone cypionate in self-administered injections, spaced 7–28 days apart. G.H. contacted James M. Dabbs about volunteering for a study on testosterone, offering personal diary entries and detailed injection records.

### *Text Samples*

*Case 1: E-mails.* D.M. supplied his unedited outgoing e-mail files, saved automatically by his Eudora e-mail program. The e-mails included messages sent to colleagues, friends, and family and were aggregated by day into 343 text files. We removed attachments and deleted replies written to him by others.

*Case 2: Journal entries.* G.H.'s text samples were different from D.M.'s in topic, target audience, and style. G.H. supplied private journal entries which were personal and reflective. A minority of them discussed testosterone or the transgender experience. The remainder covered a host of topics, from G.H.'s ambitions, worries, family, and lovers, to spectator sports. Although G.H. had been an enthusiastic diarist for many years, the present study focused only on entries between January 1999 and December 2000. Of the 730 days in this period, diary entries had been written on 266 days. G.H. photocopied all entries, marking out names and other potentially identifying information as well as work notes. All entries were then transcribed from their handwritten form.

### *Self-Ratings of Language Use and Testosterone*

At the conclusion of the study, both participants were asked about their perceptions of the treatment's psychological effects. G.H. was invited to complete a questionnaire that asked him to judge, for each of LIWC's word categories, whether he perceived an increase or a decrease in how often he used those words around the time of the injections. Ratings were on a scale ranging from −3 (*negatively related to testosterone levels*) to 3 (*positively related to testosterone levels*). In contrast, D.M. perceived no psychological effects and therefore did not complete a questionnaire.

### *Text Analysis Procedure*

The LIWC program was customized to retain only dimensions that were not highly redundant with a second dimension. Content domains that were not relevant to the hypotheses were also excluded. Most functional and linguistic categories were retained because they represented some of the most common parts of speech and because they have frequently been found to be useful markers of psychological states. Using LIWC, each of D.M.'s 343 e-mail text files and G.H.'s 266 diary text files were analyzed separately. This analysis yielded for each file the percentage of words that fit into each of the 31 retained LIWC dimensions.

## Results

### *Language Use Across the Treatment Cycles*

Depo-Testosterone has a half-life of 8 days (Pharmacia, 2002). Serum levels peak within 24 hr of administration. Of course, without blood or saliva tests, only a rough guess as to testosterone levels is possible.

The key index of the relationship between testosterone and language use was the simple Pearson correlation between the number of days after each testosterone injection and the frequency of different word types. Each testosterone cycle was treated as a mini experimental replication. By collapsing data across cycles, we minimized noise and maximized reliability for the linguistic measures collected on each day (Day 1 after an injection, Day 2 after an injection, etc.). Two types of word samples were excluded prior to analysis: (a) samples containing fewer than 81 words, which totaled 10% of D.M.'s samples and 2% of G.H.'s samples, and (b) samples on Day 0, because we did not know whether the injections were given before or after writing. In addition, both D.M. and G.H. occasionally had delayed injections, producing cycles longer than their regular cycles (about 20 days between injections for G.H. and about 19 days between injections for D.M.). Because this was an infrequent occurrence, there were fewer samples available for Days 22, 23, and so on, than there were for Days 1–19. To avoid distorting the correlations between day since last injection and language use measures by using less reliable estimates for the period preceding the next injection, we excluded samples collected on or after Day 20 of a cycle in D.M.'s case and on or after Day 21 of a cycle in G.H.'s case. After exclusions, 271 writing samples for D.M. and 244 for G.H. were retained.

For each participant, correlations were computed between the number of days after each testosterone injection and the frequency of different word types. Table 1 displays individual correlations for D.M. and G.H. together with a combined correlation weighted by the number of entries contributed by D.M. and G.H.

Table 1 is organized thematically, grouping the LIWC categories that correspond to commonly held beliefs about testosterone. The correlations are presented so that positive correlations imply that higher testosterone levels are associated with greater word use in a given category.

Two effects emerged. First, higher levels of testosterone were associated with lower levels of social words, suggesting reduced interest in social connections. Thus, as testosterone levels fell across the cycle, participants made more references to other people (rather than to objects). When data across both participants and the five social indicators were combined, results were significant.

Table 1
*Observed and Perceived Correlations of Testosterone With Word Frequencies*

| LIWC dimension | Examples | Case 1: D.M. | Case 2: G.H. | D.M. & G.H. combined | G.H.'s estimate |
|---|---|---|---|---|---|
| Aggression, dominance, sex | | | | | |
| Anger | Hate, kill | .02 | .00 | .01 | 3 |
| Swear words | Damn, bastard | .04 | .03 | .03 | 3 |
| Death | Dead, coffin | −.05 | −.03 | −.04 | 2 |
| Achievement | Win, succeed | .02 | .07 | .05 | 3 |
| Occupation | Office, work | .05 | −.05 | .00 | 2 |
| Money | Cash, dollars | −.03 | −.10 | −.06 | 2 |
| Sports | Baseball, NFL | .08 | −.08 | .01 | 3 |
| Sexual words | Sensual, penis | −.02 | .06 | .02 | 3 |
| Social connections | | | | | |
| Total social references | | −.10 | −.25** | −.17** | −1 |
| Pronouns referring to others | We, she, they | −.14* | −.23** | −.18** | 0 |
| Communication verbs | Hear, say, share | −.01 | −.20** | −.10* | −2 |
| Friends | Buddy, pal | .03 | .07 | .05 | −1 |
| Family | Mom, sister | −.01 | .02 | .01 | −1 |
| Humans | Boy, child | −.01 | .05 | .02 | 1 |
| Spatial thinking | | | | | |
| Space | Area, across, up | .07 | −.08 | .00 | 3 |
| Prepositions | To, with | .02 | .09 | .05 | 0 |
| Reasoning | | | | | |
| Long words (6+ letters) | | .05 | .07 | .06 | −1 |
| Cognitive mechanisms | Think, know | −.08 | .06 | −.01 | −1 |
| Action orientation | | | | | |
| Future tense verbs | Will, gonna | .11† | .02 | .06 | 2 |
| Certainty | Positive, certain | .07 | .04 | .06 | 1 |
| Motion | Go, move | −.07 | −.01 | −.04 | 3 |
| Feeling | | | | | |
| Positive emotions | Happy, nice | .01 | 0 | .00 | −2 |
| Optimism | Energy, upbeat | .11† | .06 | .09* | 1 |
| Positive feelings | Love, joy | −.06 | .11† | .02 | −2 |
| Negative emotions | Sad, ugly | −.03 | .04 | .00 | 3 |
| Anxiety | Worry, fear | −.02 | −.06 | −.04 | −1 |
| Sadness | Depressed, cry | −.02 | .09 | .03 | −3 |
| Feel | Touch, felt | −.04 | .19** | .07 | −2 |
| Self references | I, me, my | −.02 | .03 | .00 | −1 |

*Note.* Linguistic Inquiry and Word Count (LIWC) dimensions refer to overall word categories. Case 1 and Case 2 columns reflect Pearson correlations between word category use and days following the last injection. D.M. & G.H. combined is a weighted average of both correlations. Degrees of freedom for Case 1 = 269, for Case 2 = 242, and for combined = 513. Correlations are inverted so that positive correlations indicate that higher word frequencies were associated with higher testosterone levels. G.H.'s estimate reflects G.H.'s beliefs about the relationship between testosterone and word category usage (3 = *very strong positive relationship*, 0 = *unrelated*, and −3 = *very strong negative relationship*).
† $p \leq .10$. * $p \leq .05$. ** $p < .01$.

These results appeared to be driven by testosterone-related changes in pronouns and communication verbs, rather than changes in social nouns (e.g., *sister*, *buddy*). Results were also stronger in the case of G.H. than D.M. The second noteworthy finding was that no other consistent correlations emerged for many dimensions intuitively linked to testosterone—aggression, achievement, sexual behavior, anger, or markers of cognitive complexity.

### *Participants' Retrospective Impressions*

D.M. reported not noticing any psychological effects of the treatment, observing only that upper-body strength had been restored successfully. Unlike D.M., G.H. was aware of significant psychological changes across testosterone cycles, which he compared with his previous experiences of menstrual-cycle mood swings. The final column of Table 1 presents G.H.'s judgments of the size and direction of the relationship between testosterone level and specific linguistic categories. However, these observations turned out not to be reflected in G.H.'s language use. A correlation between G.H.'s actual and estimated columns in Table 1 was not significant and indeed was slightly negative, $r(29) = -.15$, *ns*.

## Discussion

For the two different case studies, the longer the period since the last testosterone injection, the more the participants used words connoting social relationships. Contrary to commonly held beliefs, changes in testosterone levels were unrelated to linguistic markers of mood state, aggression, sexuality, achievement, and references to perceptual or cognitive processes. Indeed, the participants'

beliefs concerning testosterone did not map onto the observed pattern of correlations.

This study represents a conservative test of the hypothesis that testosterone is related to linguistic behavior. The magnitude of the correlations was certainly modest but still noteworthy, given the nature of the measures and the dramatic differences between the cases (e.g., age, biological sex, motivations for taking testosterone, background beliefs, type of linguistic samples). We should also emphasize that the data were based on only two individuals. It is not known the degree to which testosterone levels were causally linked to any linguistic shifts. Testosterone changes may have affected the participants' behaviors, which, in turn, may have influenced how they thought and wrote.

The pattern of effects is consistent with other literatures. References to others through the use of pronouns has been found to be more common among women than among men (Groom et al., 2003). Women, of course, have lower average testosterone levels than do men. Pronoun use is also higher among nonsuicidal poets than suicidal poets (Stirman & Pennebaker, 2001), supporting the idea of pronouns as an index of how socially connected the person feels. The absence of relationships between testosterone levels and linguistic indexes of traditionally testosterone-linked variables also fits with some existing work. Animal research has shown that testosterone does not produce a general increase in dominant behavior and sexual behavior but produces an increase in these behaviors subject to the presence of situational factors, particularly uncertainty and threat (e.g., Wingfield, Ball, Dufty, Hegner, & Ramenofsky, 1987). Because our linguistic analysis assessed variation in everyday, naturalistic behaviors, it is perhaps unsurprising that it yielded a different profile of testosterone's effects than do laboratory and self-report studies. G.H.'s self-reports may also have been sensitive to situationally driven occurrences of aggressive behavior and sexual behavior that did not affect his diary-writing behaviors.

Results indicated that testosterone, at least over a 3–4-week cycle, may divert people's interests away from social connections. Behaviorally, higher testosterone levels may increase task-oriented aggression, status striving, and even the initiation of casual sexual behavior. Nevertheless, testosterone may cause people to spend less time considering the emotions, thoughts, and behaviors of others. This finding makes sense if high testosterone levels prompt people to strive for social status (e.g., Mazur & Booth, 1998). Testosterone can clear the mind and allow people to make decisions that are not colored by social considerations.

Linguistic analyses provide information and detect patterns that other measures cannot. Unlike traditional self-reports, narratives such as diaries, poetry, or letters are always available for analysis. We encourage researchers to consider adding language samples to their surveys for future investigations.

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