Original Research Article, Title: Preliminary evidence that androgen signaling is correlated with men's everyday language

Accepted manuscript; this manuscript may differ slightly from the published version.

Authors: Jennifer S. Mascaro*[a, b], Kelly E. Rentscher[c, d], Patrick D. Hackett[e], Adriana Lori[f], Alana Darcher[a], James K. Rilling[b, e, g], and Matthias R. Mehl[c]

Affiliations:

[a] Department of Family and Preventive Medicine, Emory University School of Medicine, 1841 Clifton Road NE, Rm 507, Atlanta, GA 30329, USA

[b] Center for Translational Social Neuroscience, Emory University

[c] Department of Psychology, University of Arizona, 1503 E. University Blvd., Bldg. 68, Tucson, AZ 85721, USA

[d] Cousins Center for Psychoneuroimmunology, Semel Institute for Neuroscience and Human Behavior, University of California, Los Angeles, 300 UCLA Medical Plaza, Suite 3156, Los Angeles, California 90095, USA

[e] Department of Anthropology, Emory University, 207 Anthropology Building, 1557 Dickey Drive, Atlanta, Georgia 30322, USA.

[f] Department of Human Genetics, Emory University School of Medicine, Atlanta, GA 30322, USA

[g] Department of Psychiatry and Behavioral Sciences, Emory University School of Medicine, 1639 Pierce Drive, Suite 4000, Atlanta, Georgia 30322, USA.

Number of text pages, plus bibliography: 24 pages
Number of tables, figures, graphs, and charts: 2 tables, 1 figure
Abbreviated title (running headline): Androgen signaling and men's language

***To whom correspondence should be addressed:**
Jennifer S. Mascaro, PhD
1841 Clifton Rd. N, Suite 507
Office 404.727.4301
Fax 404.727.1360
jmascar@emory.edu

Grant sponsorship: This work was supported by a Positive Neuroscience Award from the John Templeton Foundation and by NIH grant R21HD078778. Assay services were provided by the Biomarkers Core Laboratory at the Yerkes National Primate Research Center. This facility is supported by the Yerkes National Primate Research Center Base Grant 2P51RR000165-51. Blood draws were provided by the Atlanta Clinical and Translational Science Institute's Clinical Research Network, supported by the National Center for Advancing Translational Sciences of the National Institutes of Health under Award Number UL1TR000454.

Abstract

Objectives: Testosterone (T) has an integral, albeit complex, relationship with social behavior, especially in the domains of aggression and competition. However, examining this relationship in humans is challenging given the often covert and subtle nature of human aggression and status-seeking. The present study aimed to investigate whether testosterone levels and genetic polymorphisms in the AR gene are associated with social behavior, assessed via natural language use.

Methods: We used unobtrusive, behavioral, real-world ambulatory assessments of men in partnered heterosexual relationships to examine the relationship between plasma testosterone levels, variation in the androgen receptor (AR) gene, and spontaneous, everyday language in three interpersonal contexts: with romantic partners, with co-workers, and with their children.

Results: Men's testosterone levels were positively correlated with their use of achievement words with their children, and the number of *AR* CAG trinucleotide repeats was inversely correlated with their use of anger and reward words with their children. Testosterone levels were positively correlated with sexual language and with use of swear words in the presence of their partner, but not in the presence of co-workers or children.

Conclusions: Together, these results suggest that testosterone may influence social behavior by increasing the frequency of words related to aggression, sexuality, and status, and that it may alter the quality of interactions with an intimate partner by amplifying emotions via swearing.

Key Words: Testosterone; Androgen Receptor; Challenge Hypothesis; Swearing; Aggression

Introduction:

A large body of research indicates that testosterone (T) levels impact, and are in turn impacted by, social behavior (Archer, 2006; Carré & Olmstead, 2015). The *challenge hypothesis* is one prevailing theory for understanding testosterone's many influences. It proposes that testosterone (T) plays a critical role in reproductive success by mediating the trade-off between caregiving on the one hand, and aggression, dominance, and status pursuits, particularly in response to challenge and threat, on the other (Hunt, Hahn, & Wingfield, 1999; John C. Wingfield, Hegner, Dufty, & Ball, 1990). Much of the research in support of the challenge hypothesis comes from nonhuman animals and indicates that testosterone rises during the mating season in response to competition for resources and mating partners, and it is important for promoting sexual behavior (Hirschenhauser & Oliveira, 2006). Further support for the role of T in competitive behavior comes from rodent studies showing that territorial aggression is attenuated by castration and restored with testosterone replacement (Bermond, Mos, Meelis, Van der Poel, & Kruk, 1982; Kriegsfeld, Dawson, Dawson, Nelson, & Snyder, 1997).

Another large but contentious body of research examines the link between T and aggression in humans and finds some support for the relationship. For example, men's basal levels of T are correlated with observer-reports of aggression and dominance during competition (Scaramella & Brown, 1978; Slatcher, Mehta, & Josephs, 2011), and both male and female prison inmates convicted of violent crimes have higher levels of T than do those convicted of non-violent crimes (J. Dabbs & Hargrove, 1997; J. M. Dabbs, Carr, Frady, & Riad, 1995). Men with high T are more sensitive to status and dominance threats (Jack van Honk et al., 1999), which appears to be mediated by increased amygdala responses to threatening stimuli (Derntl et al., 2009; Goetz et al., 2014; Hermans, Ramsey, & van Honk, 2008; Manuck et al., 2010), reduced responses in the orbitofrontal cortex (OFC), and reduced coupling between the amygdala and OFC thought to reflect reduced regulatory control over the amygdala's response to emotion stimuli (Carré &

Olmstead, 2015; Mehta & Beer, 2010; Spielberg et al., 2014; Volman, Toni, Verhagen, & Roelofs, 2011). In the context of intimate relationships, one small study found that testosterone levels in men predicted self-reported verbal aggression and physical violence toward their domestic partner (Soler, Vinayak, & Quadagno, 2000), and another found that men with high testosterone were more likely to report having hit or thrown things at their spouse (Booth & Dabbs, 1993). More recent research has found that paternal testosterone levels were positively correlated with intimate partner aggression, as reported by the partner (Saxbe, Schetter, Simon, Adam, & Shalowitz, 2017), whereas a postpartum decline in paternal testosterone was correlated with increased relationship satisfaction, as rated by both the male and the female partner in the dyad (Saxbe, Edelstein, et al., 2017). Related, exogenous testosterone administration impairs the ability to accurately interpret others' thoughts and feelings, a cognitive component to empathy that may otherwise prevent aggressive responding (J. van Honk et al., 2011).

In addition to regulating aggression and status-seeking behavior in the context of competition, testosterone also modulates sexual behavior. In socially monogamous birds, increases in testosterone promote the initiation of spermatogenesis and reproductive behavior (John C Wingfield, 1984; John C. Wingfield et al., 1990). In humans, low levels of T are associated with reduced libido among hypogonadal men (Wang et al., 2000), and men with high levels are more likely to become a partnered father, although that may reflect the pursuit and achievement of status rather than, or in addition to, increased mating pursuits (Lee T. Gettler, McDade, Feranil, & Kuzawa, 2011).

Examining the relationship between T and social behavior in humans is challenging given the likelihood for self-report biases (because of the high evaluativeness of the assessment domain; (Paulhus & Vazire, 2007)), as well as by the possibility that T may exert a more complex and covert influence on human behavior than is observed in other species. For example, while there is evidence that T is linked with aggression and dominance behaviors in humans (J. Dabbs & Hargrove, 1997; J. M. Dabbs et al., 1995; Mehta & Beer, 2010), the relationship is less obvious in humans than in other animals, likely due to the complex and often non-violent ways in which aggression and social dominance are expressed in everyday life (Eisenegger, Haushofer, & Fehr, 2011). Similarly, the impact of T on men's sexual desire is more complex than is often portrayed, with the influence of T administration on libido and sexual activity often found only for hypogonadal men (Isidori et al., 2005), and with many studies failing to find a relationship between circulating T and self-reported sexual desire (reviewed in (Sari M van Anders, 2012)). Moreover, the influence of T on aggression will likely vary depending on the context and on interaction partners. We chose to focus on sexual, aggressive, and status-related language given the above evidence that T modulates each of these behaviors. We suspected links with sexual language would be strongest with the partner, and aggressive and status-related language would be strongest with partners and co-workers. Language with children was viewed as a category in which we would not expect to see these relationships.

The impact of testosterone on behavior will depend not only on its circulating levels, but also on the brain's sensitivity to them as reflected by properties and density of androgen receptors. For example, the number of CAG trinucleotide repeats in the first exon of the androgen receptor (AR) gene located on the x chromosome is inversely correlated with expression (Choong, Kemppainen, Zhou, & Wilson, 1996), as well as *in vitro* sensitivity of the receptor (Chamberlain, Driver, & Miesfeld, 1994), and the number of CAG repeats in the AR gene has an inverse relationship with brain activity in response to threatening facial expressions (Manuck et al., 2010). Other studies have found that CAG repeat number was inversely correlated with self-reported aggression (Butovskaya et al., 2015) and impulsivity (Aluja et al., 2015), and that men convicted of violent criminal behavior had significantly fewer CAG repeats than an age-matched cohort (Rajender et al., 2008).

The present study aimed to investigate whether testosterone levels and genetic polymorphisms in the AR gene are associated with everyday social behavior, assessed via natural language use. We utilized unobtrusive behavioral real-world ambulatory assessments to interrogate the relationship between men's testosterone, CAG repeat numbers, and word use in the context of their relationship with their romantic partner, their children, and co-workers. Specifically, we investigated the extent to which men's testosterone levels and number of *AR* CAG trinucleotide repeats are correlated with the relative frequency of their use of aggressive, sexual, and status-related language. We also tested for an interaction effect of T and CAG repeat number on linguistic variables.

Methods:

Subjects

As part of a larger study on the biological bases of paternal caregiving (Mascaro, Rentscher, Hackett, Mehl, & Rilling, 2017), we recruited 56 heterosexual, biological fathers of children age 1 or 2 years who were currently cohabitating with the child's mother (**Table 1**). Men were recruited using flyers posted around the university campus, at local parks, daycare centers, and with an electronic advertisement on Facebook. The study was approved by the Institutional Review Board, and all participants gave written informed consent. As the larger study included functional neuroimaging, participants had normal or corrected-to-normal (with contact lenses) vision and were screened and excluded for self-reported history of head trauma, seizures or other neurological disorder, claustrophobia, and for ferrous metal in any part of body. Participants were also excluded for psychiatric illness, alcoholism or any other substance abuse, and for serious medical illness.

Men were between the ages of 22 and 46 years (M = 32.92, SD = 5.22) and had between 1 and 4 children, with 2 as the modal number (M = 1.78, SD = .76). Participants were married to or cohabitating with their partner for an average duration of 6.19 years (SD = 3.52).

Procedure

After men were consented, we acquired a saliva sample for genetic analysis and then gave them a personal digital assistant (PDA) device programmed with the Electronically Activated Recorder (EAR) software (described below) and asked them to wear the device on one weekend day and one weekday. In a separate session in the laboratory, participants were fitted with an indwelling I.V. catheter and 16 ml of blood was drawn immediately upon catheterization.

Electronically Activated Recorder

The Electronically Activated Recoder (EAR) is an audio recording device that intermittently records snippets of ambient sounds while participants go about their lives and thereby yields an acoustic log of a person's day as it unfolds (Mehl, 2017, in press; Mehl, Pennebaker, Crow, Dabbs, & Price, 2001). Men wore the EAR device in a protective case clipped to their waistline. The version of the EAR used in this study consisted of a Dell Axim X50 handheld computer with the EAR software programmed to record 50 seconds every 9 minutes. In reliability analyses, this sampling rate has yielded stable estimates of daily behaviors and robust effect estimates with criterion variables (Mehl, Robbins, & große Deters, 2012). The EAR was set to record between the hours of 8 AM Sunday and 8 AM on Tuesday and, because this was part of a lager study designed to examine parenting behavior, participants were asked to store and charge the device in their child's room at night. Participants were informed of the frequency with which the EAR was set to record and were aware that the EAR could be recording any time during the 48 hour period, but they were told that they would not be able to tell when the device was recording. Nor were they told why or how researchers would use the audio recordings (Robbins, 2017).

Participants were excluded if they had fewer than 50 audio recordings during the 48 hour period (n = 3), so the final EAR data set contained 53 participants. Participants had an average of 158.04 (SD = 30.60) valid (i.e. the participant was wearing the device, and there were no technical problems), waking (i.e. the participant was not sleeping) audio files that could be coded. Of note, there were some participants who did not have recordings with co-workers, either because they did not wear the EAR at work (e.g. for confidentiality reasons) or because they did not have co-workers (e.g. stay-at-home fathers or men who worked alone). A total of 34 participants had recordings with coworkers.

A group of eight trained research assistants coded the audio files. In all cases, two research assistants independently coded all of the audio files for each participant. Coders were instructed to listen to each audio file at least twice and to use contextual information (from previous and consecutive sound files) to increase the accuracy of their codings. Coders also transcribed all of the participants' speech captured by the EAR, with the first coder creating the verbatim transcript and the second coder reviewing the transcript for accuracy. Coders were blind to the current research hypotheses. The data were collected in Atlanta, Georgia and the audio files were coded in Tucson, Arizona minimizing any chances that the research assistants would know or recognize any of the participants.

Hormones Assays

Blood samples were centrifuged at 4 ºC within 20 min of blood draw. Plasma was collected and frozen at - 80 ºC until assayed. Assays were analyzed in duplicate by the Biomarkers Core Lab of the Yerkes National Primate Research Center at Emory University using coated-tube radioimmunoassay kit (Coat-A-Count Total Testosterone, Cat No. TKTT1, Siemens, Los Angeles, CA). On the day of the assay, frozen plasma samples were thawed, centrifuged for 30 minutes at 3,000 revolutions per minute, and assayed according to the protocol provided by the manufacturer. The inter-assay CV% was 4.05% - 4.37%, and the intra-assay CV% ranged from 2.07% at 136.11 ng/dL - 2.28% at 785.81 ng/dL. The sensitivity of the assays was 6.00 – 1,667.00 ng/dL.

We were unable to obtain blood samples from one participant due to difficulties in vascular access. In addition, testosterone values from one participant were excluded because he mentioned after the blood draw that he took testosterone supplements. Therefore, the final testosterone sample included 51 participants. Blood samples were drawn between 7:30 am and 3:30 pm, but there was no correlation between the time of the blood draw and testosterone levels ($r_s = .12$, $p = .40$).

Genetic assays: Subjects provided a saliva sample for genotyping analyses using Oragene kits (DNA Genotek). DNA was extracted using automated DNA extraction by Omega-Biotek (Omegabiotek.com). CAG repeat polymorphisms in Exon 1 of the AR were genotyped using methods described previously (Mishra, Thangaraj, Mandhani, Kumar, & Mittal, 2005) with some modifications. A polymerase chain reaction (PCR) was performed using a forward primer labeled with FAM as fluorophore (5'-FAM-CAGAATCTGTTCCAGAGCGTGC) and a reverse primer (5'AAGGTTGCTGTTCCTCATCCAG 3') to amplify 10 ng dried DNA/sample in 10 ul final assay volume (1X Buffer, 1.5mM MgCl2,0.2 mM dNTP, 0.5mM each primer, 5% DMSO, 1.25 Units Amplitaq Gold). For cycling, the following touch down conditions were used: 95 °C for 5', 94°C for 1', annealing temperature starting at 63°C for 1' and going down to 60°C with 1 degree decrease, 72°C for 1' (2 cycles for the intermediate temperature and 26 cycles for the final annealean temperature of 60 °C); final extension was performed at 72°C for 10'. The PCR products for the AR length polymorphisms were run in ABI Gene Analyzer capillary detection system for fluorescently labeled PCR primers (ABI 3730). All fragments were automatically sized and examined using Applied Biosystems Genemapper 4.0 software. Two independent readers examined all electropherograms to confirm the automatically sized results. For quality control, allele frequencies and distribution were considered.

Samples with different base pair size were randomly selected for Sanger Sequencing. Briefly, after performing PCR for the CAG repeat as previously described, sample amplifications were evaluated on 2.5% agarose gel and then purified using QIA quick PCR purification kit (Qiagen). Following normalization of the PCR purified-products at 5 ng/ul, samples were cycle sequenced using BigDye terminator plus reverse primer and ran on 3130 ABI Sequencing Machine by Omega-Biotek. Electropherogramms were evaluated using *Sequencer 5.1*: for each sample, the CAG repeats were manually counted and confirmed by an independent reader. The results of this analysis consistently revealed 3 additional CAG repeats for each participant compared to GeneMapper values, and a range of 14-28 repeats for the sample (M = 22.1; SD = 3.01).

Statistical Analysis

To analyze the language captured by the EAR, we employed the Linguistic Inquiry and Word Count (LIWC) (Pennebaker, Boyd, Jordan, & Blackburn, 2015), which is currently the most extensively validated word-count based text analysis tool in the social sciences. LIWC operates by matching each word in a text to an internal dictionary that is comprised of different categories of words representing specific domains. These domains include standard linguistic dimensions (e.g., pronouns), as well as psychological constructs such as affective processes (e.g., anger), social processes (e.g., family), core drives and needs (e.g., achievement), and biological processes (e.g., sexual).

To derive information about the men's language use, the overall verbatim transcripts were first separated by interaction partner. Behavioral codings were used to discern whether the participant was talking to their romantic partner, co-workers, or children in each EAR audio file (intercoder reliabilities, ICC[1, 2] = .90, .97, .82 respectively) . Transcripts of the men's speech with each interaction partner were then submitted to LIWC analyses (in addition to a LIWC analysis of their overall word use). LIWC calculates language variables as a percentage of each participant's total number of words spoken, such that a value of 1.0 indicates that 1% of the participant's words fell into a given category (e.g. swear words). We limited our analysis to linguistic categories that we deemed conceptually related to the effects of testosterone on behavior, namely those related to (1) aggressive language: anger words (e.g. 'annoy', 'fight', 'rude', 'threat', 'yell') and swear words (e.g. 'ass', 'horseshit', 'fuck', 'prick'); (2) affiliative language (e.g. 'cuddle', 'dear', 'love', sweetie', 'together'); (3) sexual language (e.g. 'boner', 'breast', 'horny', 'porn', 'sexy'); and (4) status-related language: achievement words (e.g. 'best', 'proud', 'success', 'try'), power words (e.g. 'allow', 'boss', 'highest', 'inferior', "weak"), and reward words (e.g. 'benefit', 'bonus', 'earn', 'win').

In order to examine the correlation between men's testosterone levels, androgen receptor (AR) expression as reflected in CAG repeat number, and language, we first examined the relationship between men's age and testosterone levels since previous studies indicate that age influences both testosterone (Harman, Metter, Tobin, Pearson, & Blackman, 2001) and language (Kern et al., 2014). Given the non-normal distribution of men's language and the presence of potential outliers (de Winter, Gosling, & Potter, 2016), we conducted Spearman's rank-order correlation analyses to test if testosterone level or CAG repeat number significantly correlated with men's language. To examine the specificity of the effect of testosterone, we separately examined whether testosterone was correlated with linguistic variables in the presence of the participant's romantic partner, co-workers, or children. Because previous research indicates that the use of taboo or swear words is one way in which non-violent aggression manifests (Rassin & Muris, 2005), and the frequency of swearing is positively correlated with hostility and dominance (Fast & Funder, 2008) and negatively correlated with agreeableness (Mehl, Gosling, & Pennebaker, 2006). However, given that swearing occurs in many contexts outside of aggressive interactions, we examined the participants' transcripts to characterize the circumstances surrounding the instances of swearing in the presence of the romantic partner, co-workers, and children. Given the exploratory nature of our analyses, we first used an alpha level of .05. Tests of the hypotheses were also conducted using Bonferroni adjusted alpha levels of .001 (.05/42). Finally, we tested for an interaction effect of T X CAG repeat number on language variables using linear regression analyses in which participant age, testosterone, and CAG repeat number were entered in the first step, and T X CAG repeat number were entered in the second step

Results:

Participant age was inversely correlated with testosterone levels (r_s= -.28, $p < .05$) but not with the use of any of the linguistic variables of interest. For this reason we did not control for age in any of our subsequent analyses[1]. Men's testosterone levels significantly predicted use of anger words (r_s= .35, p = .01), swear words (r_s= .45, $p < .001$), and sexual words (r_s= .29, p = .04) used with their romantic partner (**Table 2** and **Figure 1a** and **1b**). The correlation between T and use of swear words was significant at the Bonferroni adjusted alpha levels of .001. There was a trend for men's testosterone levels to predict their use of sexual (r_s= -.30, p = .095) and reward words (r_s= .318, p = .071) with co-workers, but no correlations reached the level of significance. Testosterone levels were significantly correlated with men's use of achievement words with their toddler (r_s= .29, p = .04). Testosterone levels were not significantly correlated with men's use of affiliative words in any context. With respect to the androgen receptor (AR) gene, the number of AR CAG repeats was inversely correlated with men's use of anger words

[1] In order to verify that participant age was not a confound in our analysis, we also conducted Spearman's rank-order correlation analyses using the standardized residuals for testosterone, regressed on participant age, and there were no substantive differences in the findings (i.e. all correlations remained significant): anger words (r_s= .35, p = .01), swear words (r_s= .45, $p < .001$), and sexual words (r_s= .28, p = .05) used with their romantic partner; achievement words with their toddler (r_s= .31, p = .03).

(r_s= -.38, p = .01) and reward words (r_s= -.32, p = .03) (**Figure 1c**) with their child. The correlation between the number of AR CAG repeats and language was not driven by differences in ethnicity, as the correlation remained when only the Caucasian subset of the participants were analyzed (anger: r_s= -.54, p < .001; reward: r_s= -.61, p < .001). CAG repeat number was not correlated with language variables in any other contexts. Finally, the interaction between T and CAG repeat number was also significant (R^2 change = .07, β = -2.54, p < .05) for swearing in the presence of the partner, indicating that the impact of T on swearing was greater for men with low numbers of CAG repeats.

To further investigate the conversational context of swearing in the presence of the partner, we re-coded transcripts to evaluate whether swear words were generally directed at the partner (representative example: "shut the fuck up."), at a non-present third party (representative example: "What the hell did they do?"), or at oneself or an object (representative example: "I am cold as fuck."). Swearing directly at the partner accounted for 26% of the instances of swearing, swearing at a third party for 16%, and swearing at oneself or an object for 58%. Testosterone levels were significantly correlated with swearing in all three categories (directly at partner: r_s = .41, p = .003; at a non-present third party: r_s = .32, p = .02; and at oneself or an object: r_s = .42, p = .002).

Discussion:

Here we report that men's testosterone levels and polymorphisms of the androgen receptor gene were correlated with their use of language related to aggression, affiliation, status, and sexuality. Because the LIWC analysis counts words from each category and normalizes with respect to the men's total word count, these findings indicate that testosterone influences the relative proportion of men's linguistic content related to aggression, dominance, and sex. The most statistically robust finding was that testosterone levels were correlated with the number of swear words men used with their romantic partner, but not with co-workers or children.

Swearing has been conceptualized as an "emotional amplifier" and as a unique verbal communication tool akin to "using the horn of your car" (Jay, 2009) (p. 155). As such, swearing has been found to serve the function of emotionally connotating interactions (Jay & Janschewitz, 2008), facilitating the expression of emotions (negative and positive, but more often negative), and, most recently, even communicating authenticity or honesty (Feldman, Lian, Kosinski, & Stillwell, 2017). Importantly, swear words were coded if uttered in the presence of the romantic partner even if they were not necessarily directed at the partner (e.g. "I don't give a damn about the dog."), and more fine-grained analyses indicated that testosterone levels were positively correlated with swearing in the presence of the romantic partner regardless of context. Taken together, we interpret these data to indicate that testosterone amplifies the emotional tenor of interactions with the partner through the use of swear words.

Regarding the finding that men with high T used relatively more swear words directed at their partner, previous research indicates a negative association between men's testosterone levels and relationship satisfaction (Robin S. Edelstein, van Anders, Chopik, Goldey, & Wardecker, 2014), and men's testosterone levels have also been linked with self-reported verbal aggression and physical violence toward their domestic partner (Booth & Dabbs, 1993; Soler et al., 2000). Moreover, exogenous testosterone impairs empathic reactions that may otherwise prevent aggressive responding (J. van Honk et al., 2011). Interpreted in the context of these diverse lines of research, the present findings may indicate that T negatively impacts relationship quality through the use of swear words that can be conceptualized as a form of non-violent aggression. However, because we did not administer a measure of relationship quality, the impact of swearing on the romantic relationship is not clear within the current study, and we have no evidence that increased swearing had harmful effects on the men's' relationships.

Moreover, alternative interpretations are possible. For example, swearing might constitute a display of masculinity designed to either attract or intimidate the partner. Or, swearing might be a display of honesty (Feldman et al., 2017), which may be more common in men with high levels of T (Wibral, Dohmen, Klingmüller, Weber, & Falk, 2012). It is also possible that swearing is a method of tempering negative emotions during conflict (Philipp & Lombardo, 2017) that might have some beneficial effects on intimate relationships. We expect that examining the link between testosterone, swearing, and relationship quality will be a fruitful next step, and given the general finding that laboratory-based research tends to underestimate differences between non-distressed and distressed couples (Fincham, 2003), these data point to the EAR as a more precise and ecologically valid methodology for analyzing intimate relationship discontent.

Interestingly, we found that the impact of T on swearing depended on CAG repeat number, such that the relatively high likelihood of swearing for men with high testosterone was almost entirely mitigated if they also had high numbers of CAG repeats. Given that the influence of testosterone on behavior will depend on both the circulating levels of testosterone and on characteristics of the androgen receptor, examining the interaction of T and genetic polymorphisms of AR gene is important for a more comprehensive understanding of the androgenic influence on behavior. For example, Vermeersch and colleagues found a significant interaction between CAG repeat number and T on risk-taking and mood (Vermeersch, T'sjoen, Kaufman, Vincke, & Van Houtte, 2010). While the current result is consistent with research indicating that CAG repeat number is inversely correlated with the sensitivity of the androgen receptor (Chamberlain et al., 1994), we interpret this finding with some caution given that detecting moderation effects requires a relatively large sample size (McClelland & Judd, 1993) and because the relationship between T and CAG repeat number appears to be complex and dependent on circulating levels of T (Lee T Gettler et al., 2017; Ryan et al., 2017).

The finding that men's testosterone levels were positively correlated with the relative amount of sexual language they used with their romantic partner is consistent with research linking testosterone with libido (Corona, Isidori, Aversa, Burnett, & Maggi; Robin S Edelstein, Chopik, & Kean, 2011; Wang et al., 2000). It is important to note that these data do not indicate that men with high T engaged in more sexual behavior with their partner, or whether more sexual language is indicative of relationship satisfaction or outcomes. Within married couples, testosterone levels are negatively correlated with relationship quality and amount of time spent with one's partner (Gray, Kahlenberg, Barrett, Lipson, & Ellison, 2002), and so these data may best be interpreted as men with lower T engaging in relatively more non-sexual dialogue with their partner. Recent research indicates that postpartum declines in T are related to positive relationship outcomes (Saxbe, Edelstein, et al., 2017; Saxbe, Schetter, et al., 2017), and future research using the EAR could test the hypothesis that reductions in T lead to relatively more non-sexual dialogue and improved relationship quality.

Also of note, increased libido is only one possible mechanistic explanation for the link between T and sexual language. For example, men with elevated T may have also varied on mood (Amanatkar, Chibnall, Seo, Manepalli, & Grossberg, 2014), general motivation (Aarts & van Honk, 2009) or reward processing (Hermans et al., 2010), or other personality factors (Smeets-Janssen et al., 2015), all of which have been shown to be influenced by T and that may in turn increase sexual language with the partner. Nor can we rule out the possibility that men who use more sexually explicit language with their partner experience an increase in T, an interpretation that would be consistent with studies showing that visual (for example, (Robin S Edelstein et al., 2011) and olfactory (Miller & Maner, 2010) sexual stimuli increases testosterone levels. Related, men who use more sexual language with their partner may engage in more sexual behavior, which in men leads to a relatively protracted increase in T (i.e. 12-24 hours after sexual activity) (reviewed in (Goldey & van Anders, 2015)).

That the link between T and sexual language was only significant for men's language with their partner was somewhat unexpected given research linking testosterone levels with extra-pair mating and infidelity. For example, experimental manipulation of testosterone is causally associated with increased mating effort and with extra-pair fertilizations in socially monogamous birds (Raouf, Parker, Ketterson, Nolan, & Ziegenfus, 1997; John C Wingfield, 1984). In humans, testosterone levels in partnered men are correlated with a desire to engage in extra-partner sexual activity (Sari M Van Anders & Goldey, 2010) and with having multiple partners within a polygynous society (Alvergne, Faurie, & Raymond, 2009), and testosterone levels are associated with lifetime number of sex partners in elderly men (Pollet, van der Meij, Cobey, & Buunk, 2011). In fact, in the current study T was *inversely* correlated with sexual language used with co-workers, although this relationship only reached the level of a trend. A previous set of case studies in men receiving testosterone supplementation also found no effect of T on the prevalence of sexual language in emails and journal entries (Pennebaker, Groom, Loew, & Dabbs, 2004). While this previous study only examined changes in the use of sexual language for two individuals, one of whom was unmarried, the findings are consistent with the findings of the current study in indicating that T differentially impacts sexual language depending on the context and conversational partner.

With respect to language with their children, men's relative number of anger words were inversely correlated with the number of CAG repeats, indicating that men who were more sensitive to testosterone used harsher emotional language with their children. A large body of research indicates that testosterone attenuates paternal nurturing behavior (Goymann & Dávila, 2017) and that a reduction in T accompanies engaged paternal caregiving (Lee T. Gettler et al., 2011; Gray et al., 2002). In another published report with an overlapping set of men we found that CAG repeat numbers were positively correlated with men's neural response to infant cries in brain regions important for empathy, including in the anterior insula and bilateral IFG

(Mascaro, Hackett, Gouzoules, Lori, & Rilling, 2013), and taken with the current finding is consistent with the idea that androgen sensitivity interferes with paternal nurturing. CAG repeat number was also inversely correlated with men's use of reward language (e.g. 'bonus', 'win') with their child. Similarly, men's use of achievement language (e.g. 'proud', 'try') was positively correlated with testosterone levels, which together suggest that androgen signaling increases men's use of status-related language with their children. While we cannot definitively link the use of status-related language with child outcomes, either positive or negative, these findings highlight the point that the effects of testosterone may not be deleterious for all aspects of parental care and that parenting is not always a "low T" endeavor (Sari M Van Anders, Goldey, & Kuo, 2011).

A related and important interpretation of these data is that the relationship between men's testosterone and language depends largely on context and on interaction partner. For example, testosterone was related to the number of achievement words men used when they interacted with their children, but not with their partner or co-workers, raising the intriguing idea that men with high testosterone seek status on behalf of, or via, their children. The link between testosterone and both swearing and sexual language is only present for men's interactions with their romantic partners. There is some evidence that testosterone works via the orbitofrontal cortex to disinhibit emotional impulses from the limbic system (Mehta & Beer, 2010), and it may be that testosterone is allowing the expression of anti-social (swearing) or sexual utterances that are normally suppressed in men with lower testosterone and in contexts where such language may be more toxic or tabooed (e.g., with children and co-workers). If it is the case that T has a larger impact on men's aggressive and sexual language with their partners primarily because it is a context of relative disinhibition in comparison with interactions with children or colleagues, then the findings presented here indicate that testosterone is most influential in contexts of low inhibition. Alternatively, swearing and sexual language were less frequent with co-workers and children and we had fewer recordings with co-workers, and thus there may have been insufficient variance for testosterone to explain.

Several limitations are worth note, as they may hinder our interpretation of these data. Given the cross-sectional design, we are unable to test causative or temporally covarying mechanisms of circulating testosterone. While we interpret these findings as indicative of testosterone leading to an increase in aggressive, sexual, and status-related language, a large body of research indicates that social behavior alters testosterone levels (Carré & Olmstead, 2015; Sari M. van Anders, Steiger, & Goldey, 2015), and it remains possible that the use of relatively more aggression, sexual, or status-related language leads to increased levels of testosterone. Future research might employ a longitudinal design to examine changes in language that immediately accompany changes in T in order to clarify the direction of causality. This is particularly important given the diurnal variation of, and context-dependent fluctuations in, T. Related, the measure of T used here was from a single measurement acquired on a different day than the audio recordings. Although previous research indicates that testosterone has high test–retest reliability (Sellers, Mehl, & Josephs, 2007), acquiring and averaging plasma T levels over multiple time points during the collection of the recordings could more closely link linguistic behavior with circulating levels of T.

The findings also indicate future directions that were not possible within the present study. A growing body of research indicates that aggression and dominance should be studied as an interaction of testosterone and cortisol (Carré & Mehta, 2011; Pfattheicher, 2017), and future research could use the EAR to test the “dual-hormone hypothesis”. In addition, this was a wide-ranging exploratory analysis and only the relationship between plasma T and swearing survived Bonferroni correction for multiple comparisons. Finally, our relatively small sample consisted of Western, relatively highly educated, partnered men with children, and an important next step will be to examine whether the relationship between testosterone and language is similar for women and for men in other cultures and demographic categories.

Despite limitations, the present findings advance our understanding of the relationship between testosterone and social behavior by providing preliminary evidence that linguistic variables related to aggression, sexual behavior, and status covary with testosterone levels, with genetic polymorphisms of the AR gene, and with their interaction. While the study was exploratory, the relationship between T and swearing with the partner was robust to multiple comparison correction and points to a novel behavioral outcome that covaries with testosterone. The use of the EAR revealed relationships between men's T and language use with their partner that may be meaningful for understanding relationship satisfaction, and this line of research may be particularly important given the more than 12-fold increase in global testosterone sales since 2000 (Handelsman, 2013).

Acknowledgements

This work was supported by a Positive Neuroscience Award from the John Templeton Foundation and by NIH grant R21HD078778. Assay services were provided by the Biomarkers Core Laboratory at the Yerkes National Primate Research Center. This facility is supported by the Yerkes National Primate Research Center Base Grant 2P51RR000165-51. Blood draws were provided by the Atlanta Clinical and Translational Science Institute's Clinical Research Network, supported by the National Center for Advancing Translational Sciences of the National Institutes of Health under Award Number UL1TR000454. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

Author contributions

The study was designed by J.K.R., M.R.M., and J.S.M. Data collection, preparation, and analysis were conducted by J.S.M., K.E.R., and P.D.H., and the manuscript was written by J.S.M., M.R.M., and J.K.R. The authors have no conflicts of interest to disclose.

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Table 1: Descriptive statistics

	Mean (SD)
Participant age	32.92 (5.22)
Relationship length	6.19 (3.52)
Number of children	1.78 (.76)
Participant ethnicity	
White	36
Hispanic	4
Black	8
Asian	3
Other or not reported	0
Household income (year)	$87,000 (56,000)
Years education	17.23 (2.45)
Testosterone (ng/dL)	432.16 (150.30)
CAG Repeat number	22.13 (3.01)
Anger words	
Talking to partner	0.23% (0.28)
Talking to co-worker	0.21% (0.34)
Talking to toddler	0.22% (0.66)
Swear words	
Talking to partner	0.15% (0.24)
Talking to co-worker	0.12% (0.29)
Talking to toddler	0.06% (0.24)
Affiliative words	
Talking to partner	1.76% (1.07)
Talking to co-worker	1.45% (1.17)
Talking to toddler	2.41% (1.44)
Sexual words	
Talking to partner	0.05% (0.11)

Talking to co-worker	0.03% (0.06)
Talking to toddler	0.01% (0.07)
Achievement words	
Talking to partner	0.51% (0.41)
Talking to co-worker	1.03% (1.47)
Talking to toddler	0.57% (0.87)
Power words	
Talking to partner	1.28% (0.73)
Talking to co-worker	1.26% (0.91)
Talking to toddler	2.00% (1.79)
Reward words	
Talking to partner	1.70% (0.80)
Talking to co-worker	1.78% (1.16)
Talking to toddler	2.35% (1.59)

Table 2: Spearman's rank-order correlations between T and CAG repeats and linguistic variables according to interaction partner(s).

		Anger	Swear words	Affiliative words	Sexual	Achieve-ment	Power	Reward
Talking to partner	T	0.35*	**0.45****	-0.04	0.29*	0.22	0.13	0.02
	CAG repeats	0.14	0.08	0.26	-0.01	-0.07	-0.26	0.05
Talking to co-worker	T	0.08	-0.09	0.05	-0.30	0.07	0.06	0.32
	CAG repeats	-0.17	-0.27	-0.18	-0.01	-0.16	-0.17	-0.08
Talking to toddler	T	0.10	0.11	-0.02	-0.05	0.29*	0.07	0.04
	CAG repeats	-0.38**	-0.20	0.11	-0.19	0.06	-0.12	-0.32*

*Correlation is significant at the 0.05 level
**Correlation is significant at the 0.01 level
Correlation is significant at the Bonferroni-corrected level of .001

Figure 1: Spearman's rank-order correlation between (a) swearing in the context of the partner and testosterone levels; (b) sexual language in the context of the partner and testosterone

levels; and (c) reward language in the context of the child and CAG repeat number. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1495268/