



Figure 1. Importance of social context and gender in moderating testosterone (T) – behavior associations. Behavioral studies indicate that social context (e.g., winning or losing a dominance contest; presence or absence of a status threat) influences the association between T and status seeking behaviors (e.g., aggression, competitiveness). Pharmacological challenge experiments indicate that the association between T administration and status seeking behaviors depends on gender. Thus, it will be important to consider these moderating variables in future studies that examine the role of T in promoting human social behavior.

[5–7]. What this group of studies show is that T is a powerful predictor of status-relevant behavior, but only when an individual's status is threatened [5–10]. In the absence of status threat (e.g., when one has won a dominance battle or when status is not relevant), T fails to predict behavior (see Figure 1). These findings provide strong support for a relationship between T and status-seeking behavior and provide an answer to the first 'outstanding' question in Box 1 in [1].

In summary, a more inclusive consideration of the literature than that provided in [1] supports the conclusion that (i) T increases reactive aggression in men (but not women), and (ii) T is most strongly related to status-relevant behaviors *after* social status is threatened

(e.g., after losing a dominance battle). We believe strongly that increased attention to the role of gender and the social environment in moderating T-behavior associations is crucial to understanding how and when T influences complex social behavior.

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Letters Response

No sound evidence for a gender-specific effect of testosterone administration on aggressive motivation exists: reply to Josephs *et al.*

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We thank Josephs *et al.* for their comments on our paper [1]. For several reasons, we are not convinced of their first claim that two previous studies indicate an aggression-enhancing causal role of testosterone in men. First, one of the studies [2] only had an effective sample size of $N = 6$ and the two studies cited by Josephs *et al.* are in fact only one dataset, as the data in [2] are entirely contained in [3]. Second, we did not take into account [3] because the study

was designed to investigate the behavioral effects of anabolic androgenic steroids (AAS) which produce considerable side effects and are also considered to be toxic [4]. Pope *et al.* [3] injected testosterone cypionate (a testosterone derivative with a long half-life) over extended periods of time in very high dosages. Such procedures have clearly documented secondary effects on other hormone systems, including the reproductive system, the stress axis and even on thyroid levels. In fact, some researchers argue that any potential positive effects of AAS on aggression in males may be observed only because of secondary changes in

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thyroid levels [5]. Furthermore, it is likely that subjects became aware of peripheral effects that result from this AAS treatment (such as increased muscle tone and volume) and were, therefore, not blind as to whether they received testosterone or placebo. Thus, if subjects became aware that they received testosterone, folk beliefs about the effects of testosterone [6] could also have driven the increase in 'aggressive' responding reported in [3]. In sum, the pharmacological design employed in [3] is not useful to learn about testosterone's causal effects on human social behavior.

Josephs *et al.* claim that the causal influence of testosterone on status-related behavior is modulated by gender ([1], Figure 1). However, only evidence from testosterone administration studies can answer this question conclusively but, unfortunately, there exists at present no study that compares the causal effect of testosterone on men and women in an integrated study design.

We agree with Josephs *et al.*'s assessment that previous correlational studies such as [7,8] (see also their comment for further references) provide interesting suggestive evidence for the view that testosterone may be a driver of status-related behaviors in situations in which the subjects' status is under threat. In this context, it is, however, also worthwhile to mention that several administration studies show behavioural effects of testosterone without status threats as part of the study design (e.g., [9,10]). In addition, although suggestive, the correlational studies [7,8] do not prove that testosterone causes status-related behaviors because baseline testosterone levels may be correlated with a host of other (personality or environmental) variables, which may be the true cause of the observed correlation between baseline testosterone (or changes in testosterone) and behavior. Let us assume, for example, that living in a competitive environment that poses permanent threats to status causes a high level of baseline testosterone and a high level of competitiveness. In this scenario, the subjects' baseline testosterone levels will be correlated with their willingness to compete for

status but this correlation is spurious and tells us nothing about the causal effect of testosterone on the willingness to defend one's status.

To summarize, we agree with Josephs *et al.* that previous correlational studies such as [7,8] provide interesting evidence for the idea that testosterone may cause status-related behaviors when status is under threat, but due to their correlational nature the studies are also open to different interpretations. We are not convinced, however, by the claim that previous studies provide evidence for the hypothesis that testosterone causes aggressive motivations in men.

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