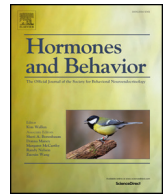




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## Preliminary evidence that testosterone's association with aggression depends on self-construal<sup>☆</sup>

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### ABSTRACT

A contribution to a special issue on Hormones and Human Competition.

Previous research and theory suggest testosterone is an important hormone for modulating aggression and self-regulation. We propose that self-construal, a culturally-relevant difference in how individuals define the self in relation to others, may be an important moderator of the relationship between testosterone and behaviors linked to aggression. Within two studies (Study 1  $N = 80$ ; Study 2  $N = 237$ ) and an integrated data analysis, we find evidence suggesting that acute testosterone changes in men are positively associated with aggressive behavior for those with more independent self-construals, whereas basal testosterone is negatively associated with aggression when individuals have more interdependent self-construals. Although preliminary, these findings suggest that self-construal moderates the association between testosterone and aggression, thereby paving the way toward future work examining the potential cultural moderation of the behavioral effects of testosterone.

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### 1. Introduction

Violence and aggression are highly detrimental to society, resulting in over 1.3 million deaths each year worldwide (World Health Organization, 2014). Yet, although aggression often leads to undesirable outcomes, it likely exists to serve important evolutionary functions such as defending territory, self-defense, and acquiring resources necessary for survival (Hawley, 1999). Many causes and risk factors contribute to the emergence of aggression. These include hormones, genetics, negative affect, observational learning, violent media, psychopathy, deficits in brain regions associated with aggression, poor self-control, alcohol, the presence of weapons and aggressive cues, narcissism, serotonin deficits, poor socialization, bullying, and culture, among others (see Bushman and Huesmann, 2010; Carré et al., 2011;

Ferguson and Beaver, 2009; Ferguson and Dyck, 2012; Ferguson and Kilburn, 2009; Huesmann, 2007; Mehta et al., 2013; for reviews). To advance the etiology of aggression, it is critical to adopt an integrative account of aggressive behavior that incorporates biological, psychological, and socio-cultural factors.

One hormone relevant to poor self-regulation and aggression is testosterone (e.g., Archer et al., 2005; Mazur and Booth, 2014). Previous research suggests testosterone is linked to increased aggression and impulsivity. Indeed, exogenously administered testosterone in humans can augment sensitivity to reward (van Honk et al., 2004), reactivity to threats in regions of the brain associated with aggression (Goetz et al., 2014), and aggressive behavior (e.g., Pope et al., 2000). At present, there is a heightened recognition of the need to differentiate between basal testosterone (stable level of endogenous testosterone) and acute testosterone changes (see Carré et al., 2011; Mazur and Booth, 1998; for reviews).

Basal testosterone is implicated in aggressive/antisocial behaviors, but the effect size is relatively weak in humans (see Archer et al., 2005). Complicating this matter, basal testosterone may promote prosocial behavior in women (e.g., Boksem et al., 2013; Eisenegger et al., 2010) and cooperation with ingroup members during intergroup competition (Diekhof et al., 2014; Reimers and Diekhof, 2015).

In contrast, acute testosterone fluctuations may be more relevant for aggression. Numerous studies examine various contexts that alter

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testosterone concentrations, including competitive interactions (e.g., Carré et al., 2013; Zilioli et al., 2014), social rejection (Geniole et al., 2011), aggressive provocation (Carré et al., 2014), and interactions with aggressive stimuli (Klinesmith et al., 2006). These studies show a reliable link between momentary increases of testosterone and aggression/antisocial behavior (See Carré and Olmstead, 2015 for a review).

Testosterone concentrations generally fluctuate in response to competitive interactions, often with concentrations elevated in winners relative to losers (see Geniole et al., *in press*, this issue, for meta-analysis). As predicted by the Biosocial Model of Status (Mazur, 1985), a rise in testosterone may serve to facilitate dominant behaviors designed to gain or protect social status. On the other hand, a decrease in testosterone serves to facilitate submissive behaviors aimed at avoiding further threats to status (Mazur, 1985). Indeed, rises in testosterone during competitive interactions often predict future elevated aggression and effect size estimates of testosterone changes have been of moderate to large size (Carré et al., 2009; Carré et al., 2013; Carré et al., 2014; Geniole et al., 2011; Klinesmith et al., 2006; see Carré and Olmstead, 2015 for a review). One potential caveat is that in one study post-competition testosterone changes predict female athletes' motivation to reconcile with opponents after a competition (Casto and Edwards, 2016). Hence, more work is needed to identify potential moderators of the link between both basal testosterone and testosterone dynamics and aggression/antisocial behavior.

### 1.1. Individual differences as contexts for understanding testosterone and aggression

Previous work suggests some personality and socio-cultural factors as potentially important moderators of the link between testosterone and aggression and other social behaviors. For example, trait dominance appears to influence the extent to which testosterone is associated with dominant mating behaviors (Slatcher et al., 2011). Further, trait dominance is associated with the degree to which exogenously administered testosterone affects victory-dependent competitive decision making in women (Mehta et al., 2015a) and aggressive behavior in men (Carré et al., *in press*). Additionally, being in a committed relationship is associated with decreased testosterone for women, but this effect is evident only for those who are low in both extraversion and sensation seeking (Costa et al., 2015). Testosterone responses to competition are associated with aggressive behavior primarily in low anxiety men (Norman et al., 2014), whereas men with higher grandiose narcissism show greater testosterone responses while engaging in aggression (Lobbestael et al., 2014). Overall, this work suggests that the link between testosterone and aggression is stronger for those who are inclined toward competition (i.e., those who are high in dominance, extraversion, and sensation seeking).

### 1.2. The role of self-construal

One important individual difference that might predispose how people respond to competition concerns "self-construal," or how people mentally represent the self as independent from others or interdependent with them (Cross et al., 2011; Markus and Kitayama, 1991). Self-construal was initially coined to describe differences in self-definition and self-representation between people in individualistic (e.g., United States of America) and collectivistic cultures (e.g., Japan) (Markus and Kitayama, 1991). Within any given culture, these two construals are often orthogonal and thus can co-exist within the same person (Singelis, 1994). Nevertheless, researchers have also suggested that the two construals could be combined such that self-construal is defined by the relative balance between independent versus interdependent self-construals (Kitayama et al., 2009).

Those with more independent self-construals (hereby called independents) view the self as being unique and independent of others,

defining the self by internal attributes, such as attitudes, abilities, and personality traits. Previous work implicates a more independent self-construal in individual competitive behaviors that maximize gains for the self, rather than for others. This work often employs social dilemma games, which test competitive vs. cooperative behaviors when individual and collective interests conflict (Dawes, 1980). For example, cooperation in a social dilemma game decreases as a function of independent self-construal (Utz, 2004). People from an independent culture (Americans) also tend to cooperate less in social dilemma games than those from an interdependent culture (Vietnamese) (Parks and Vu, 1994). In contrast, those with interdependent self-construals (hereby called interdependents) view themselves as connected to and motivationally-oriented toward others, defining the self by external, situational factors (e.g., groups, relationships, communities) (Cross et al., 2011; Markus and Kitayama, 1991).

Altogether, we hypothesize that individual competition should be more important and more likely as a function of greater independence, whereas it may be less of a concern and less likely with greater interdependence. To the extent that the link between testosterone and aggression is more robust among those motivated during individual competitions (Carré and McCormick, 2008; Eisenegger et al., 2011; Mehta and Josephs, 2006), we anticipate that this link is more robust and reliable as a function of independence dominance and, conversely, less robust and weaker as a function of interdependence dominance.

The link between testosterone and aggression could be conceived at multiple levels. The first goal of the current work was to determine whether self-construal would moderate the link between testosterone and aggression and, moreover, this moderation effect might differ for basal testosterone level versus acute testosterone changes (Aims 1 and 2). We also tested whether competition induced testosterone dynamics would differ as a function of self-construal (Aim 3).

#### 1.2.1. Aim 1: Does self-construal moderate the association between basal testosterone and aggression?

Cross and Madson (1997) theorized that interdependents avoid aggression as it could jeopardize social connections or demonstrate poor self-regulation. Interdependence is associated with decreased engagement in cyber-bullying and victimizing in adolescents (Cetin et al., 2012). Cross-cultural comparisons have revealed that individualistic, independent groups are more likely to initiate competitive conflicts and use more competitive, dominant conflict resolution tactics compared to more interdependent groups, who adapt obliging, harmonizing tactics (Oetzel, 1998a, 1998b). Differences in self-construal also explain conflict management strategies better than ethnicity or sex (Ting-Toomey et al., 2001). Overall, this suggests that interdependence may de-couple the association between testosterone and aggression. The basal testosterone-aggression association may be small in humans because interdependents suppress aggressive behaviors or motivations to aggress when testosterone levels are elevated. Rather than investigating bivariate associations between basal testosterone and aggression, or self-construal and aggression, Aim 1 is focused to test an interactive model. Thus, in Aim 1, we investigated whether the association between basal testosterone and aggression differs between independents and interdependents.

#### 1.2.2. Aim 2: Does self-construal moderate the association between testosterone changes and aggression?

Researchers have reasoned that acute changes in testosterone more robustly accounts for reactive aggression than basal testosterone (e.g., Carré et al., 2011). Because more interdependent individuals (as previously mentioned) with high testosterone may avoid acting aggressively when testosterone is elevated, self-construal might also moderate associations between testosterone dynamics and aggression.

### 1.2.3. Aim 3: Does self-construal moderate the effects of competitive outcomes on testosterone responses?

Competitive outcomes might be less likely to modulate testosterone in interdependents compared to independents. Independents seek to distinguish themselves in comparison to others in status, while interdependents do not (Heine et al., 1999; Lalwani & Savitt, 2009; but see Cai et al., 2010). So, because interdependents define the self in terms of groups and social identities, the perceived status of interdependents may not be impacted by the outcomes of individualistic competitions than independents. Perhaps because interdependent people might gain status through harmonizing with others, defeating another person in a competition would not lead to an increase in status. Additionally, because interdependents define the self in terms of groups and social identities, the perceived status of interdependent individuals, relative to independent individuals, might be less affected by individualistic competitive outcomes.

### 1.3. Overview and hypotheses

Across two studies and an integrated data analysis, we tested three aims related to testosterone, self-construal, and aggression. First, we investigated whether the effects of basal testosterone on aggression were moderated by self-construal, hypothesizing that basal testosterone would be positively associated with aggression in independents, but not interdependents. Second, we investigated whether the association between testosterone responses to competition and subsequent aggression was specific to independents, rather than interdependents. Third, we investigated whether testosterone responses to competition were specific to those with independent self-construals. Study 1 investigated whether self-construal moderated the relationship between testosterone (basal/pre-competition and reactive/post-competition) to winning a competition on subsequent aggressive behavior which occurred after men experienced a string of victories. Study 2 extended these findings by using a relatively large sample of men and women who were experimentally assigned to win or lose a competition. Following Studies 1 and 2, we performed an integrated data analysis of both studies to more conclusively establish how self-construal is associated with testosterone and aggressive behavior.

## 2. Study 1

### 2.1. Methods

#### 2.1.1. Participants

Eighty men ( $M_{age} = 21.58$ ,  $SD = 3.16$ ; 86.25% Caucasian, 5% Asian; 2.5% First Nations, 6.25% Other) were recruited from the participation pool at Nipissing University and ads placed around campus (including Canadore College) in a larger protocol investigating testosterone and aggressive behavior (Norman et al., 2014). Participants were compensated with either course credit and a \$5 honorarium or a \$15 honorarium in lieu of course credit. Study sessions were run between 11 am and 6 pm to reduce diurnal endocrine variation (Schultheiss and Stanton, 2009). With a two-tailed alpha of 0.05, this sample was substantially powered for detecting large effects ( $|r| = 0.50$ , power > 0.99), adequately powered for medium effects ( $|r| = 0.30$ , power = 0.78), and inadequately powered for detecting small effects ( $|r| = 0.10$ , power = 0.14). Study 1 was conducted in accordance with the Declaration of Helsinki.

#### 2.1.2. Materials and procedure

Participants completed informed consent and a set of questionnaires including the 24-item Self-Construal Scale (SCS; Singelis, 1994). Participants were asked to rate their agreement with 24 items on a 7-point Likert scale (1 = Strongly Disagree, 7 = Strongly Agree). Example items included “My happiness depends on the happiness of those around me” (interdependent dimension) and “My personal identity,

independent of others, is very important to me” (independent dimension). Both independent (Cronbach's  $\alpha = 0.73$ ) and interdependent (Cronbach's  $\alpha = 0.65$ ) factors had acceptable reliability and were uncorrelated ( $r = -0.08$ ,  $p = 0.498$ ). For parsimony, and consistent with previous work examining dimensions of self-construal and individual-collectivism (Gardner et al., 1999; Kitayama et al., 2014; Na and Kitayama, 2011; Nakashima et al., 2008; van Horen et al., 2008), interdependence scores were subtracted from independent scores, resulting in one index of relative self-construal where high scores indicated a more independent self-construal, and low scores indicated a more interdependent self-construal.

**2.1.2.1. Video game competition and saliva samples.** After completing questionnaires, participants provided a pre-competition saliva sample by passively drooling 1–2 mL of saliva into a polystyrene culture tube. Participants then played a boxing game (part of the game “Kinect Sports [Microsoft]”) on an XBOX 360 gaming system with a Kinect sensor. In this activity, participants played repeated rounds of boxing against a computer-controlled opponent. The Kinect sensor detects limb movements and gestures, allowing participants to easily control the game similar to an actual boxing match and deliver strikes (e.g., jabs, hooks, haymakers, uppercuts) to their opponent and block attacks. The computer could in turn perform a variety of attacks and also block participants' attacks. Both the computer opponent and player had a ‘health meter’ that would deplete as hits were delivered and slowly restore in the absence of receiving hits. Winning the game was determined by three possible conditions: 1) the opponent failed to get up within 10 s after being knocked down, 2) the opponent was knocked down three times in a match, or 3) the player dealt a greater amount of damage than the opponent in 90 s. The third of these possible victory conditions did not occur in our study.

Participants played multiple rounds of the boxing game for approximately 15 min. Unknown to the participants, the difficulty was set to the lowest setting, allowing participants to win all matches ( $M = 4.92$  victories,  $SD = 0.68$ , 100% of matches resulted in a victory). Participants also completed a brief questionnaire on their perceptions of the game difficulty and their effort (“How difficult did you find this game?” and “How hard did you try to win this game?”, 1 = not at all, 5 = very much so). Although the game was perceived as being relatively easy ( $M = 1.49$ ,  $SD = 0.69$ ), participants generally indicated putting forward strong effort to win ( $M = 4.05$ , 1.18). Participants also provided a post-competition saliva sample 5 min after the game (i.e., 20 min after the competition started).

As part of a larger research protocol examining the association between self-control and aggression, participants were also randomly assigned to a self-control depletion condition or a control condition after the competition (DeWall et al., 2007). The key concept in the design of this task is that self-control failures (e.g., aggressive behavior) are more likely to occur after someone has already exercised self-control. In this task, participants watched a silent film clip of an interview with one-syllable words appearing on the bottom right section of the screen. Participants in the depletion condition were instructed to exercise willpower to ignore the words presented onscreen, whereas those in the control condition were only told to watch the video. Recent meta-analytic work published after our data collection has suggested that self-control depletion tasks do not affect later instances of self-regulation (Carter et al., 2015). Consistent with these meta-analytic findings, controlling for this experimental manipulation did not alter the presented findings in Study 1, nor did the experimental condition moderate any reported tests of our hypotheses.<sup>1</sup>

<sup>1</sup> To test this, we re-ran all models conducted in Study 1 (Aims 1 and 2) as hierarchical regression models including the self-control depletion condition as covariate and a moderator of the testosterone X self-construal interactions. We also examined partial correlations of all study variables controlling for the depletion condition.



**2.1.2.2. Point subtraction aggression paradigm.** After the depletion manipulation, participants engaged in the Point Subtraction Aggression Paradigm (PSAP; Cherek et al., 2006), a widely used behavioral measure of costly reactive aggression, where they competed with another male participant (actually a computer program). A previously taken photo of the participant and a standardized picture of the opponent (computer program) were displayed on the screen during the task to boost belief that participants were actually playing a real opponent. To support this belief, a confederate was placed in an adjacent testing room who was simultaneously being briefed on the protocol. The participant and confederate did not have any physical or visual contact. Participants were informed that the goal of the game was to win as many points as possible, and that these points could later be exchanged for money. Participants were presented with three potential responses in-game: pressing button 1 a hundred consecutive times would gain participants one point (reward); pressing button 2 ten consecutive times would steal a point from the other player (aggression); and pressing button 3 ten consecutive times would briefly protect points from being stolen by the opponent (protection). After 45 s of playing the task, points began to be stolen from participants, and this was attributed to the other player stealing the points. Participants were told that although they could press button 2 to remove points from the other player, they were assigned to the condition where they did not get to keep the stolen points. Thus, stealing points from the other player was a costly act of reactive aggression. Participants played the game for 10 min in one block. To compute aggressive behavior, we used the total number of aggressive button presses as the outcome ( $M = 216.79$ ,  $SD = 169.13$ ). Due to a computer error, aggression data from two participants was lost.

A very small amount of variability in button 2 presses involved presses that occurred within the first 45 s ( $M = 2.27\%$  of the points;  $SD = 0.04$ ). Because participants were not provoked until 45 s into the task, these responses can be considered 'unprovoked' aggression, which was displayed by 33% of our sample in Study 1. Because this portion of analysis is consistent with unprovoked aggression, we analyzed whether testosterone and self-construal were associated with unprovoked aggression, finding a similar pattern of results to our findings with total aggression scores (see Supplemental Materials).

### 2.1.3. Salivary hormone analysis

Saliva samples were stored at  $-60\text{ }^{\circ}\text{C}$  until assayed for testosterone using commercially available kits (DRG International, NJ). The average intra-assay coefficient of variation (CV) was 5.67% and the average inter-assay coefficient of variation was 14.80%.

### 2.1.4. Statistical analyses

Outliers were Winsorized to  $\pm 3$  SDs. Testosterone reactivity was computed by regressing post-competition testosterone concentrations (Winsorized) onto pre-competition testosterone concentrations (Winsorized) and saving the unstandardized residuals (Carré et al., 2013; Welker and Carré, 2014). This index of change presents an index of testosterone change that is statistically independent of basal testosterone. Indices of change such as percentage change relative to baseline are often negatively correlated with basal testosterone (e.g., Welker and Carré, 2015), reflecting a tendency for individuals with higher basal hormone concentrations to show less change.<sup>2</sup> By computing residualized testosterone change, the index of change computed is statistically independent from basal testosterone, as residuals would represent change scores that are unexplained by basal testosterone. Basal testosterone analyses used raw, Winsorized values of pre-competition testosterone.

To test our hypotheses related to self-construal moderating the associations between testosterone and aggression, we conducted

<sup>2</sup> Indeed, we found a negative trend of association between basal testosterone and percentage testosterone change in Study 1 ( $r = -0.16$ ,  $p = 0.151$ ) and a significant negative correlation in Study 2 ( $r = -0.25$ ,  $p < 0.001$ ).

moderated regression analyses using Process (Hayes, 2013). Moderated regression analysis is an analysis that investigates effects that vary across conditions—termed *conditional effects* or *simple slopes* (e.g., the relationship between testosterone and aggression when self-construal is more interdependent vs. independent). Moderated regression analysis also allows researchers to test whether a moderator variable (e.g., self-construal) changes the relationship between a predictor variable (e.g., testosterone) and an outcome (e.g., aggression). All predictor variables were mean-centered prior to computing the interaction terms. These analyses examined main effects of testosterone residuals and self-construal, along with the testosterone residuals  $\times$  self-construal interaction. Additionally, because aggression scores were positively skewed, we used square-root transformed values of aggression after adding a constant of 1 (Tabachnik and Fidell, 2007). Using untransformed aggression scores did not alter the significance or directions of any reported results. Effect sizes are provided in the metric of the partial  $r$ , which indicates the correlation between two variables holding other predictors constant (Cohen et al., 2003).

Because researchers are often interested in the magnitude of effects at conditional values of self-construal ( $\pm 1$  SDs), we provided partial  $r$  values for the simple slopes using the established formula

$$r = \sqrt{(t^2/(t^2 + df))}$$

## 2.2. Results

### 2.2.1. Preliminary analyses

Bivariate correlations and descriptive statistics for all variables are presented in Table 1. Self-construal was not associated with basal testosterone, testosterone reactivity, or aggression ( $|rs| \leq 0.11$ ,  $ps \geq 0.331$ ). Basal testosterone was inversely associated with aggression ( $r = -0.23$ ,  $p = 0.043$ ), but there was no association between testosterone reactivity and aggression ( $r = 0.05$ ,  $p = 0.664$ ). Additionally, testosterone did not significantly change from the beginning ( $M = 81.20$ ,  $SD = 25.76$ ) to the end ( $M = 79.31$ ,  $SD = 29.07$ ) of competition ( $t(79) = 0.82$ ,  $p = 0.413$ ,  $d = 0.09$ ), suggesting that participants did not uniformly change in testosterone during competition.

### 2.2.2. Aim 1: Does self-construal moderate the association between basal testosterone and aggression?

We examined if self-construal moderated the association between pre-competition testosterone and aggression. The pre-competition testosterone  $\times$  self-construal interaction was significant ( $b = 0.07$ ,

**Table 1**  
Correlations, regression models, and descriptive statistics for Study 1.

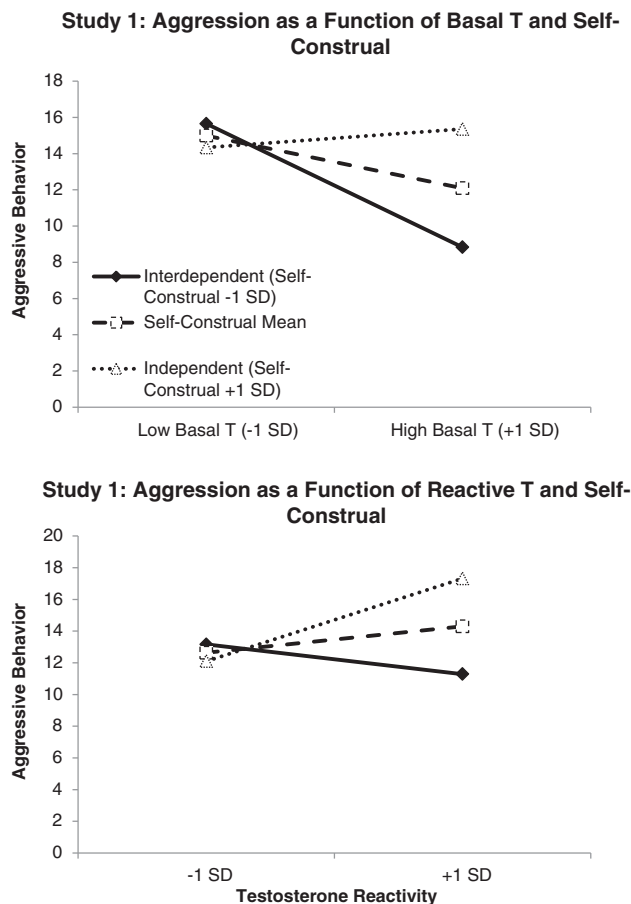
Variables	1	2	3	4	5	M	SD	N
1. Pre-competition T	–					81.21	25.76	80
2. Post competition T	0.72***	–				79.31	29.07	80
3. Testosterone reactivity	0.00	0.69***	–			0.00	20.08	80
4. Self-construal	–0.11	–0.12	–0.06	–		–0.17	1.11	80
5. Aggressive behavior (sqrt)	–0.23*	–0.14	0.05	0.19†	–	13.35	6.33	78
Regression models	B		t		p			
Aim 1 – outcome: total aggression								
Basal T	–0.06		–2.14		0.036			
Self-construal	1.17		1.90		0.061			
Self-construal $\times$ basal T	0.07		2.57		0.012			
Aim 2 – outcome: total aggression								
T reactivity	0.04		1.10		0.275			
Self-construal	1.11		1.75		0.084			
Self-construal $\times$ T reactivity	0.08		1.70		0.094			

Note: Total Aggression Scores were square root transformed. \*\*\* $p < 0.001$ , \*\* $p < 0.01$ , \* $p < 0.05$ , † $p < 0.10$ .

$t(74) = 2.57, p = 0.012, 95\% \text{ CI}[0.015, 0.121], \text{ partial } r = 0.29$ ; See Fig. 1). Specifically, when self-construals were more interdependent, pre-competition testosterone was negatively associated with aggressive behavior ( $b = -0.13, t(74) = -3.26, p = 0.002, 95\% \text{ CI}[-0.21, -0.05], \text{ partial } r = 0.35$ ). There was no association between pre-competition testosterone when self-construals were more independent ( $b = 0.02, t(74) = 0.51, p = 0.611, 95\% \text{ CI}[-0.057, 0.10], \text{ partial } r = 0.06$ ).

### 2.2.3. Aim 2: Does self-construal moderate the association between testosterone changes and aggression?

The hypothesized self-construal  $\times$  testosterone reactivity interaction on aggression was non-significant ( $b = 0.08, t(74) = 1.70, p = 0.094, 95\% \text{ CI}[-0.014, 0.17], \text{ partial } r = 0.19$ ). Although this interaction was nonsignificant, we explored the simple slopes present in this interaction to compare the pattern of results to those of Study 2 and a later aggregate analysis of both studies (See Fig. 1). The direction of the relationship between testosterone changes and aggressive behavior was in a positive direction for independents ( $b = 0.13, t(74) = 1.74, p = 0.085, 95\% \text{ CI}[-0.018, 0.276], \text{ partial } r = 0.20$ ), but not interdependents ( $b = -0.05, t(74) = -0.90, p = 0.374, 95\% \text{ CI}[-0.15, 0.06], \text{ partial } r = 0.10$ ). The above model also contained a non-significant main effect of self-construal indicating greater aggressive behavior in independents ( $b = 1.11, t(74) = 1.75, p = 0.084, 95\% \text{ CI}[-0.15, 2.38], \text{ partial } r = 0.20$ ). Testosterone reactivity was not associated with aggressive behavior as a main effect ( $b = 0.04, t(74) = 1.10, p = 0.275, 95\% \text{ CI}[-0.014, 0.171]$ ).



Note: Simple slopes are plotted at the mean and  $\pm 1$  SDs of Self-Construal, as well as  $\pm 1$  SDs of testosterone residuals.

**Fig. 1.** Moderation of how basal testosterone and testosterone reactivity are associated with aggression in Study 1. Note: Simple slopes are plotted at the mean and  $\pm 1$  SDs of self-construal, as well as  $\pm 1$  SDs of testosterone residuals.

### 2.3. Discussion

Study 1 found that basal testosterone was not associated with aggression among independents but this relationship was negative for interdependents. Although the hypothesized testosterone reactivity  $\times$  self-construal interaction did not reach significance, the pattern of the interaction was in line with our hypotheses where there was a positive trend in the association between testosterone reactivity and aggression in independents, but not for interdependents. Study 1 was not without limitations. First, this sample consisted exclusively of men, leaving it unclear whether this interaction occurred in women. Second, it is uncertain whether this effect occurs in the context of competitive interactions as a whole, or whether it is specific to winners or losers of a competition. Additionally, given the smaller sample size from which we examined this non-significant interaction effect, it was necessary to replicate these findings and test these hypotheses with a larger sample size.

### 3. Study 2

In a reanalysis of previously published data (Carré et al., 2013), we sought to replicate and extend the findings of Study 1. As Study 1 was composed of only men assigned to win a competition, Study 2 represents an improvement over Study 1 by examining the effects of competitive outcomes on aggressive behavior in a relatively large mixed-gender sample. In the original study by Carré et al. (2013), testosterone responses to competition mediated the effects of competitive outcome on subsequent aggressive behavior in men. Specifically, male winners were more aggressive in a subsequent interaction, in part, because they demonstrated a larger increase in testosterone during the competitive interaction. Again, we tested whether self-construal moderated the association between basal testosterone and aggression (Aim 1) and the association between testosterone changes and aggression (Aim 2). We also investigated whether self-construal moderated the effects of competitive outcomes on testosterone changes (Aim 3). Specifically, winning may be associated with testosterone increases relative to losing, but only among independents—a finding consistent with the idea that independents perhaps find competitive activities more rewarding (Cross and Madson, 1997; Houston et al., 2005). This finding would be consistent with the results of Study 1 whereby behavioral effects of testosterone reactivity were specific to independents. Thus, our analyses in Study 2 address each of these goals (Aims 1–3).

### 3.1. Methods

#### 3.1.1. Participants

Two-hundred and thirty-seven undergraduate students (114 men, 123 women;  $M_{age} = 21.73, SD = 4.66$ ) were recruited from the Wayne State University subject participation pool and participated for partial course credit and a \$10 honorarium. The sample was diverse (46% Caucasian, 19% African American, 15.2% Asian, 0.4% Native American, 3.8% Bi-racial, 13.9% Other, and 1.7% did not report race). To reduce the effects of diurnal variation in testosterone, all saliva samples were collected between 11 am and 5 pm. The sample size of Study 2 was substantially powered (two-tailed  $\alpha = 0.05$ ) for assessing large effects ( $|r| = 0.50, \text{ power} > 0.99$ ), substantially powered for medium effects ( $|r| = 0.30, \text{ power} > 0.99$ ), and inadequately powered for small effects ( $|r| = 0.10, \text{ power} = 0.34$ ). Data collection for Study 2 was in accordance with the Declaration of Helsinki.

#### 3.1.2. Materials and procedure

Participants arrived in the lab and completed informed consent followed by personality and demographics questionnaires including the Self-Construal Scale (Singelis, 1994), and self-construal was calculated in the same manner as Study 1. Both independent and interdependent factors showed acceptable internal consistency (Cronbach's  $\alpha$ s =

0.61 and 0.66, respectively) and a non-significant correlation between each other ( $r = 0.12, p = 0.076$ ).

**3.1.2.1. Video game competition and saliva samples.** Participants were randomly assigned to play either boxing or volleyball (available as activities through the game “Kinect Sports”) on the XBOX 360 gaming console with a Kinect motion-sensing input device. Similar to Study 1, the motion-sensing properties of the Kinect device allowed participants to control the game with physical movements, similar to a real volleyball game or boxing match. The boxing game was the same activity as was used in Study 1. The volleyball game entailed a volleyball game of player and a computer-controlled teammate against a pair of computer controlled opponents. The winning team was determined as the first team to reach 7 points. The player could use the motion controls to perform several different volley ball skills to win the game (e.g., serving, passing, setting, blocking, jumping, and spiking). Participants were unknowingly randomly assigned to either win or lose, and this manipulation was facilitated by preprogramming the game to the easiest or most challenging difficulty setting prior to participants beginning the game. Participants played multiple rounds for approximately 15 min. Winners won 93.75% of matches whereas losers lost 99.78% of matches, on average. Saliva samples were collected before and after competition (same timeline as Study 1) to assess basal and reactive testosterone concentrations.

**Table 2**  
Correlations, regression models, and descriptive statistics for Study 2 in men and women.

Men - variables	1	2	3	4	5	M	SD	N
1. Pre-competition T	–					92.61	35.95	111
2. Post-competition T	0.79***	–				85.54	34.38	111
3. Testosterone reactivity	–0.10	0.53***	–			3.54	21.15	109
4. Self-construal	0.13	0.10	–0.01	–		0.32	0.83	114
5. Total aggression (sqrt)	–0.01	0.10	0.19†	0.07	–	18.46	9.56	108
Women - variables	1	2	3	4	5	M	SD	N
1. Pre-competition T	–					40.92	20.00	122
2. Post-competition T	0.63***	–				36.13	17.67	121
3. Testosterone reactivity	–0.35***	0.51***	–			–3.21	14.47	120
4. Self-construal	0.17†	0.12	–0.10	–		0.31	0.93	122
5. Total aggression (sqrt)	–0.02	0.02	0.04	0.11	–	18.12	8.89	118
Moderated regression models for Aims 1 & 2	Men			Women				
	B	t	p	B	t	p		
Aim 1 – outcome: total aggression								
Basal T	–0.01	–0.51	0.614	–0.02	–0.39	0.699		
Self-construal	0.82	0.72	0.475	1.26	1.36	0.177		
Basal T × self-construal	0.03	0.86	0.393	–0.05	–1.36	0.177		
Aim 2 – outcome: total aggression								
Testosterone reactivity	0.09	1.98	0.051	0.02	0.26	0.798		
Self-construal	0.41	0.36	0.723	1.31	1.37	0.175		
T reactivity × self-construal	0.08	1.47	0.147	0.08	1.10	0.274		
Moderated regression model - Aim 3	Men			Women				
Outcome: T reactivity								
Competitive outcome	6.04	2.67	0.008					
Self-construal	–1.26	–0.96	0.336					
Sex	–6.80	–3.01	0.003					
Outcome × self-construal	1.42	0.54	0.588					
Sex × self-construal	0.27	0.10	0.919					
Outcome × sex	–20.04	–4.43	<0.001					
Outcome × sex × self construal	–13.17	–2.51	0.013					

Note: Total aggression scores were square root transformed. \*\*\* $p < 0.001$ , \*\* $p < 0.01$ , \* $p < 0.05$ , † $p < 0.06$ .

**3.1.2.2. Point subtraction aggression paradigm.** Similar to Study 1, participants played the PSAP. The procedure and computation of aggression were consistent with Study 1, with the exception that participants completed the task in three 7-minute blocks. After the PSAP, participants were debriefed and dismissed. Paralleling Study 1, results are presented as average aggression presses from the three blocks and analyses were conducted on square-root transformed values. Again, the overall pattern of results did not change when using untransformed results.<sup>3</sup>

**3.1.3. Salivary hormone analysis**

Saliva samples were collected and stored in polystyrene tubes, frozen at  $-20\text{ }^{\circ}\text{C}$  until assayed. Saliva samples were assayed in duplicate using immunoassay kits from DRG International. The average intra-assay CVs were 9.30% (male samples) and 12.47% (female samples), and the average inter = assay CV was 13.10%.

**3.1.4. Statistical analyses**

Testosterone outliers were Winsorized to  $\pm 3$  SDs. Similar to Study 1, changes in testosterone were computed as residualized change and our aims were tested via moderated regression analysis. Because previous analysis of this dataset (Carré et al., 2013) revealed that victory-dependent testosterone reactivity to competition predicted aggressive behavior only in men, we analyzed data relevant to Aims 1 and 2 for men and women separately. Similar to Study 1, analyses used moderated regression analysis using Process.

**3.2. Results**

**3.2.1. Preliminary analyses**

Descriptive statistics and bivariate correlations for men and women are presented in Table 2. We additionally present the primary regression models for Aims 1–3 in this table.<sup>4</sup>

**3.2.2. Aim 1: Does self-construal moderate the association between basal testosterone and aggression?**

Baseline testosterone was not associated with total aggressive behavior (square root transformed) in men ( $r = -0.01, p = 0.911$ ) or women ( $r = -0.02, p = 0.803$ ). This association for aggression was not moderated by self-construal or competitive outcome in either men or women ( $ps \geq 0.177$ ). Although these interactions failed to reach statistical significance, we explored the simple slopes in order to interpret the findings in light of Study 1 and our later integrated data analysis. The patterns of simple slopes for men showed the same general pattern found in Study 1, characterized by a small, nonsignificant negative relationship in interdependent men ( $b = -0.04, t(101) = -0.83, p = 0.410, 95\% \text{ CI: } [-0.13, 0.05], \text{ partial } r = -0.08$ ) but a near-zero relationship in independent men ( $b = 0.01, t(101) = 0.25, p = 0.803, 95\% \text{ CI: } [-0.06, 0.07], \text{ partial } r = 0.02$ ). Women’s simple slopes did not show this pattern ( $b = 0.03, t(112) = 0.54, p = 0.589, 95\% \text{ CI: } [-0.08, 0.15]$ ,

<sup>3</sup> In contrast to Study 1, we did not have data available to differentiate between unprovoked and reactive aggression responses in Study 2.

<sup>4</sup> We conducted a 3-way mixed ANOVA (Competition Outcome X Gender X Time [Pre vs. Post Competition]) to illustrate the pattern of testosterone reactivity in raw scores rather than residuals as reported by Carré et al. (2013). Our results (in raw scores rather than residuals) were characterized by a significant Outcome X Gender X Time Interaction ( $Wilk's \lambda = 0.932, F(1225) = 16.51, p < 0.001, \eta_p^2 = 0.07$ ). To explore this, we conducted simple effects tests of time across gender and competitive outcomes, finding that testosterone changes (in the metric of pg/mL, uncorrected for baseline testosterone) were primarily driven by male losers (from  $M = 93.88, SD = 37.50$  to  $M = 79.76, SD = 31.67, p < 0.001, \eta_p^2 = 0.14$ ) rather than winners (from  $M = 91.83, SD = 34.38$  to  $M = 93.47, SD = 36.10, p = 0.523, \eta_p^2 = 0.00$ ). In females, testosterone changes were primarily driven by winners (from  $M = 41.65, SD = 18.14$  to  $M = 35.47, SD = 16.71, p = 0.011, \eta_p^2 = 0.03$ ), rather than losers (from  $M = 39.96, SD = 20.59$  to  $M = 37.04, SD = 18.04, p = 0.227, \eta_p^2 = 0.01$ ). The conditional time X outcome interaction was significant for men ( $F(1107) = 17.09, p < 0.001$ ) but not women ( $F(1118) = 1.26, p = 0.265$ ), indicating that testosterone responses were differentiated between winners and losers in men, but not women. Raw changes in testosterone were very strongly correlated with residualized changes ( $r = 0.93, p < 0.001$ ).



**Table 3**  
Correlations and regression models for the integrated data analysis in men.

Variables	1	2	3	4	5
1. Pre-competition T	–				
2. Post competition T	0.76***	–			
3. Testosterone reactivity	–0.06	0.59***	–		
4. Self-construal	0.03	0.01	–0.03	–	
5. Aggressive behavior	–0.11	0.00	0.13†	0.12	–

Regression models	B	t	p	Partial r
Aim 1 – outcome: total aggression (standardized within each study)				
Basal T	–0.152	–2.02	0.045	0.15
Self-construal	0.126	1.75	0.082	0.13
Self-construal × basal T	0.165	2.26	0.025	0.17
Aim 2 – outcome: total aggression (standardized within each study)				
T reactivity	0.150	2.05	0.042	0.15
Self-construal	0.099	1.35	0.180	0.10
Self-construal × T reactivity	0.166	2.09	0.038	0.15
Aim 3 – outcome: T reactivity				
Outcome	0.552	3.57	<0.001	0.25
Self-construal	–0.048	–0.69	0.494	0.05
Self-construal × outcome	0.239	1.50	0.136	0.11

Note: †p < 0.10, \*p < 0.05, \*\*\*p < 0.001.

partial  $r = 0.05$  for interdependents,  $b = -0.06$ ,  $t(112) = -1.22$ ,  $p = 0.225$  95% CI:  $[-0.16, 0.04]$ , partial  $r = -0.11$  for independents).

**3.2.3. Aim 2: Does self-construal moderate the association between testosterone changes and aggression?**

We examined if self-construal moderated the effects of testosterone reactivity on aggression in men and women. Specifically, we conducted moderated regression analyses on the effects of testosterone residuals, self-construal, and their cross-products in men and women separately. Within men, the testosterone reactivity × self-construal interaction was nonsignificant ( $b = 0.08$ ,  $t(99) = 1.46$ ,  $p = 0.147$ , partial  $r = 0.15$ ), indicating a failure to replicate the testosterone reactivity × self-construal interaction in Study 1. However, the simple slopes were in the pattern as hypothesized. The conditional effect of testosterone on aggression was positive in more independent men ( $b = 0.15$ ,  $t(99) = 2.41$ ,  $p = 0.018$ , partial  $r = 0.24$ ) but not interdependent men ( $b = 0.02$ ,  $t(99) = 0.37$ ,  $p = 0.713$ , partial  $r = 0.04$ ). This nonsignificant testosterone reactivity × self-construal interaction was not further moderated by competitive outcome when it was included as a moderator added to the previous model ( $b = -0.07$ ,  $t(95) = -0.49$ ,  $p = 0.626$ ). For women, the testosterone reactivity × self-construal interaction effect was not robust ( $b = 0.08$ ,  $t(110) = 1.10$ ,  $p = 0.274$ ), and simple slopes were not significant at  $\pm 1$  SDs ( $ps \geq 0.256$ ). For total aggression, this two-way interaction was also not further moderated by competitive outcome ( $b = -0.04$ ,  $t(106) = -0.227$ ,  $p = 0.821$ ).<sup>5</sup>

As an additional analysis for Aim 2, we investigated whether the above tested interaction between testosterone reactivity and self-construal was present across both men and women, controlling for sex. This analysis again resulted in a nonsignificant interaction ( $b = 0.06$ ,  $t(212) = 1.55$ ,  $p = 0.124$ , partial  $r = 0.11$ ). However, simple slopes suggested testosterone reactivity was more positively associated with aggression in more independent participants ( $b = 0.11$ ,  $t(212) = 2.48$ ,  $p = 0.014$ , partial  $r = 0.17$ ) compared to more interdependent participants ( $b = 0.01$ ,  $t(212) = 0.22$ ,  $p = 0.827$ , partial  $r = 0.02$ ).<sup>6</sup>

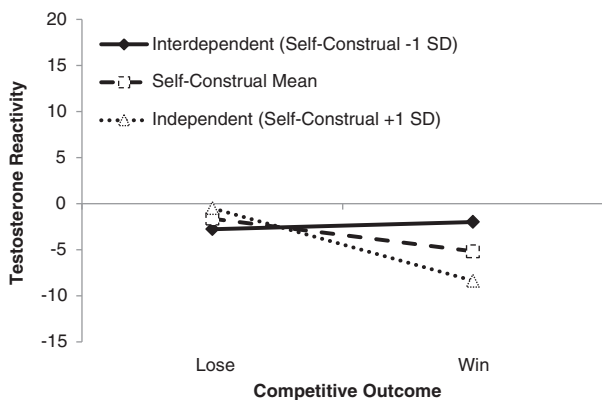
**3.2.4. Aim 3: Does self-construal moderate the effects of competitive outcomes on testosterone responses?**

Moderated regression analysis was conducted with testosterone reactivity regressed on self-construal, outcome, sex, and all possible cross-products. There was a significant three-way outcome × gender × self-construal interaction effect ( $b = -13.17$ ,  $t(220) = -2.51$ ,  $p = 0.013$ , 95% CI  $[-23.52, -2.82]$ , partial  $r = 0.17$ ). The results of this interaction are presented in Fig. 3. Decomposing this interaction revealed that in men, there was a significant conditional self-construal × competitive outcome interaction ( $b = 8.29$ ,  $t(220) = 2.13$ ,  $p = 0.035$ , 95% CI  $[0.60, 15.98]$ , partial  $r = 0.14$ ). Within men, competitive outcomes affected testosterone reactivity particularly in independents ( $b = 23.87$ ,  $t(220) = 4.75$ ,  $p < 0.001$ , 95% CI  $[14.52, 33.23]$ , partial  $r = 0.32$ ) whereby winning or losing was associated with an increase or decrease in testosterone, respectively, whereas among interdependent men, this effect was attenuated ( $b = 9.12$ ,  $t(220) = 1.91$ ,  $p = 0.057$ , 95% CI  $[-0.28, 18.52]$ , partial  $r = 0.13$ ). This conditional self-construal × competitive

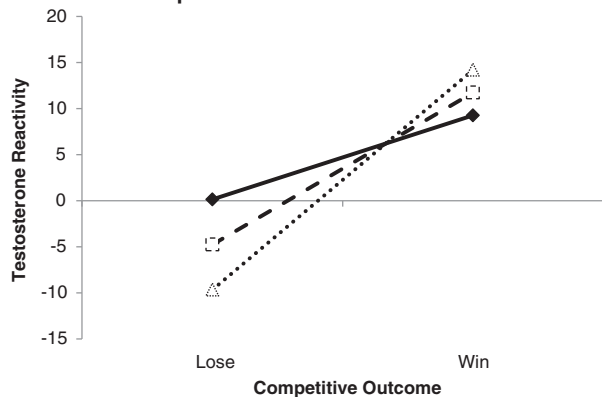
<sup>5</sup> We also examined the testosterone reactivity X self-construal specifically in male winners and losers separately. There was not a significant testosterone reactivity X self-construal interaction for either winners or losers ( $ps \geq 0.589$ ).

<sup>6</sup> At the request of a reviewer, we also examined if the basal/reactive testosterone X self-construal interactions investigated in Aims 1 and 2 were moderated by competitive outcome. Specifically, we tested for the presence of significant basal testosterone X self-construal X outcome and Testosterone reactivity X Self-Construal X Competition interactions within men and women. None of these interactions were statistically significant ( $ps \geq 0.636$ ). Additionally, we also tested whether sex moderated the primary analyses investigated in Aims 1 and 2 by testing whether aggressive behavior was predicted by a sex X basal testosterone X self-construal interaction and a sex X testosterone reactivity X self-construal interaction. Because we were analyzing men and women's testosterone as a predictor, we collapsed our data across men and women by standardizing basal testosterone and testosterone reactivity within sex (e.g., Welker et al., 2014). Neither of these interactions were statistically significant ( $ps \geq 0.136$ ).

**Women's Testosterone Reactivity as a function of Competitive Outcome and Self-Construal**



**Men's Testosterone Reactivity as a function of Competitive Outcome and Self-Construal**



Note: Simple slopes are plotted at the mean and  $\pm 1$  SDs of Self-Construal.

**Fig. 2.** Men and women's testosterone reactivity as a function of competitive outcome and self-construal in Study 2. Note: Simple slopes are plotted at the mean and  $\pm 1$  SDs of self-construal.

outcome interaction was not significant in women ( $b = -4.88$ ,  $t(220) = -1.39$ ,  $p = 0.167$ , 95% CI[-11.80, 2.05], partial  $r = 0.09$ ).

### 3.3. Discussion

In contrast to Study 1, Study 2 failed to find a significant interaction between either basal testosterone and self-construal or testosterone reactivity and self-construal. However, Study 2 expanded on the results of Study 1 by showing that victory and loss dependent changes in testosterone were specific to independent men. Despite these nonsignificant findings, the general pattern of results was consistent with the notion that self-construal may moderate the testosterone-aggression association. Overall, it is necessary to evaluate the patterns of these results conclusively across both studies in the present investigation.

## 4. Integrated data analysis of studies 1 and 2

### 4.1. Overview of the analyses

To establish clearer estimates of the moderation effects of competition, testosterone, and self-construal in men with greater statistical power, we conducted an integrated data analysis across our two studies (Curran and Hussong, 2009). This approach was used to increase statistical power, provide more precise estimation of effects, and to help communicate the magnitude of our reported effects. We aggregated our data from the two studies, standardizing aggression scores (which were already square-root transformed) within each study and using them as an aggregate, similar to the work of others (e.g., Mehta et al., 2015b). Before we addressed our primary aims of testing moderation, we also examined the associations between men's basal testosterone, self-construal, and testosterone reactivity, and aggression. Intercorrelations and regression models tested are presented in Table 3. Additionally, we present the simple slopes of all analyses within Fig. 2.

#### 4.1.1. Aim 1: Does self-construal moderate the association between basal testosterone and aggression?

First, we examined whether the effects of men's basal testosterone on aggressive behavior (from Studies 1 and 2) were moderated by self-construal. These results yielded a significant basal testosterone  $\times$  self-construal interaction ( $b = 0.16$ ,  $t(179) = 2.26$ ,  $p = 0.025$ , 95% CI: [0.021, 0.308],  $r_{\text{partial}} = 0.17$ ). In interdependents, testosterone was negatively associated with aggression ( $b = -0.32$ ,  $t(179) = -2.73$ ,  $p = 0.007$ ,  $r_{\text{partial}} = 0.20$ ). However, the association was nonsignificant in independent men ( $b = 0.01$ ,  $t(179) = 0.16$ ,  $p = 0.875$ ,  $r_{\text{partial}} = 0.01$ ).

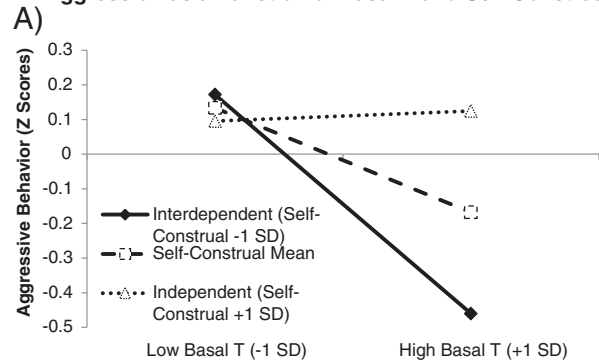
#### 4.1.2. Aim 2: Does self-construal moderate the association between testosterone changes and aggression?

Next, we examined whether self-construal moderated the effects of testosterone reactivity on aggression in men. The testosterone reactivity and self-construal interaction was significant ( $b = 0.17$ ,  $t(177) = 2.09$ ,  $p = 0.038$ , 95% CI: [0.010, 0.322],  $r_{\text{partial}} = 0.15$ ). Decomposing this interaction revealed that testosterone changes were positively associated with aggression in independents (+1 SD,  $b = 0.32$ ,  $t(177) = 2.78$ ,  $p = 0.007$ ,  $r_{\text{partial}} = 0.20$ ) but this association was nonsignificant for interdependents (-1 SD,  $b = -0.02$ ,  $t(177) = -0.18$ ,  $p = 0.854$ ,  $r_{\text{partial}} = 0.01$ ).

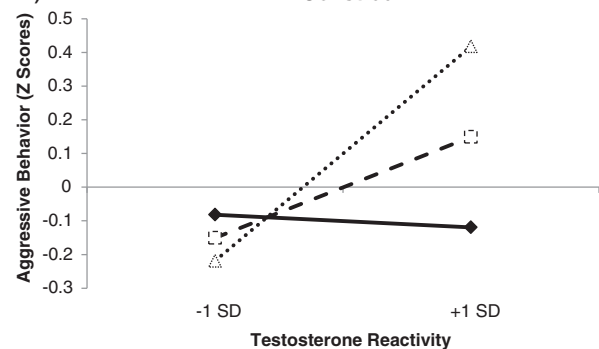
#### 4.1.3. Aim 3: Does self-construal moderate the effects of competitive outcomes on testosterone responses?

Third, we examined whether the effect of competitive outcomes on men's testosterone (residualized from pre- and post-competition testosterone scores across the studies) was moderated by self-construal. Across both studies, the interaction between competitive outcomes and self-construal was nonsignificant in men ( $b = 0.24$ ,  $t(185) = 1.50$ ,  $p = 0.136$ , 95% CI: [-0.08, 0.55],  $r_{\text{partial}} = 0.11$ ). However, to compare the results in light of the findings of Studies 1 and 2, we interpreted

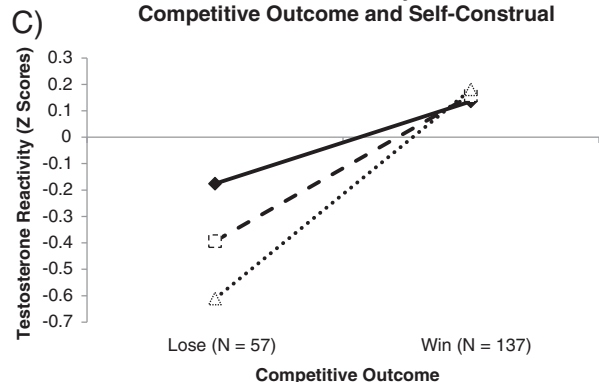
### Aggression as a Function of Basal T and Self-Construal



### Aggression as a Function of Reactive T and Self-Construal



### Men's Testosterone Reactivity as a function of Competitive Outcome and Self-Construal



Note: Simple slopes are plotted at the mean and  $\pm 1$  SDs of Self-Construal.

Fig. 3. Summary of the self-construal moderation effects tested in the integrated data analysis. Note: Simple slopes are plotted at the mean and  $\pm 1$  SDs of self-construal.

the simple slopes of this interaction. The simple slopes pattern suggested an effect of competitive outcomes on testosterone changes in independent men, where winners of the competition had higher testosterone residuals than losers (-1 SD,  $b = 0.79$ ,  $t(185) = 3.47$ ,  $p < 0.001$ ,  $r_{\text{partial}} = 0.25$ ), compared to interdependent men (+1 SD,  $b = 0.31$ ,  $t(185) = 1.43$ ,  $p = 0.153$ ,  $r_{\text{partial}} = 0.10$ ).

### 4.2. Discussion

Overall, the integrated data analysis presents a better estimate of the moderation of the testosterone-aggression association by self-construal, as well as self-construal's moderation of the effects of competitive outcomes on testosterone reactivity. Across both studies, the integrated data analysis found evidence suggesting that self-construal may moderate the association between basal testosterone and aggression (Aim 1)



and testosterone reactivity and aggression (Aim 2). The possibility that self-construal moderates the effect of competitive outcomes on testosterone reactivity (Aim 3) was not supported.

Although the integrated data analysis provided greater statistical power than Studies 1 and 2 alone, it was not without limitations. The integrated data analysis would be substantially improved if it were conducted on more than two studies, each examining winning and losing conditions, rather than one condition or the other (such as with Study 1). The lack of a loss condition in Study 1, as well as the design characteristics in each study (e.g., different competitive games, inclusion of a self-control depletion condition) potentially obscure the ability to generalize about the results across both studies, and create possible confounds when examining Aim 3. Differences in the design characteristics in multiple studies create ostensible barriers to generalizing across studies. However, once more data has accumulated examining self-construal, testosterone, competition, or aggressive behavior, researchers may be better poised for integratively examining these effects across multiple studies. Researchers may also be better poised to do this analysis by quantitatively accounting for any possible sources of between-study heterogeneity (Curran and Hussong, 2009).

## 5. General discussion

The current research provides preliminary data suggesting that self-construal may moderate associations between testosterone (basal and reactive) and aggressive behavior. Although Study 2 did not replicate all of the findings of Study 1, the pattern of the results and integrative data analysis suggests self-construal is an important factor for understanding the endocrinology of competition and aggression. Furthermore, the cultural variability of differences in self-construal (Markus and Kitayama, 1991) suggests that cultural contexts may alter the link between testosterone and aggression. This finding is consistent with emerging research in cultural neuroscience suggesting culture can alter the links between psychological and physiological processes (see Kitayama and Park, 2010 for a review).

The present research did not assess specific psychological mechanisms that may explain how self-construal may alter relationships between testosterone and aggressive behavior. One possible explanation involves the motivation to dominate others. Researchers have distinguished between different ways that individuals are motivated to achieve power and dominance over others (McClelland, 1975; Schultheiss et al., 1999; Schultheiss and Rhode, 2002; Winter, 1973). Powerful and dominant individuals can dominate others either prosocially or through assertive means. The former of these means, often called socialized power (“S power;” Winter, 1973) involves expressing dominance via benevolent means (e.g., helping others, providing advice, providing resources and protection). The latter, however, known as personalized power (“P Power;” Winter, 1973), entails achieving power through assertiveness and force (e.g., aggression, threats, coercion). Among U.S. men, P power is positively associated with testosterone after a victory; in contrast, when S power was also high, P power was negatively associated with testosterone (Schultheiss et al., 1999). Because interdependents are motivated to fit in, and achieve status through social harmony (Markus and Kitayama, 1991), interdependents might show increased effects of testosterone reactivity when status is achieved through socialized means (e.g., prosocial behavior). In turn, testosterone responses in these contexts might predict prosocial dominance behaviors, such as generosity (Flynn et al., 2006), donations in a public goods game (e.g., Andreoni, 1988) or providing help to a stranger (DeWall et al., 2008).

For independents, aggression and antisocial acts of dominance may be used to gain status. Because the current research investigated these effects within a competitive context, this may explain the absence of the relationship between testosterone reactivity and aggression in interdependence that did not emerge in these studies. This may also help further explain recent findings showing that testosterone

promotes prosocial behavior in the presence or absence of competition (Boksem et al., 2013; Casto and Edwards, 2016).

Because a cluster of traits may modulate the associations between testosterone and social behavior, future work is needed to disentangle how these traits are related to testosterone function. For instance, in addition to power motive, anxiety and dominance have been thought to modulate how testosterone affects social behavior (Carré et al., 2009; Norman et al., 2014; Slatcher et al., 2011; Mehta et al., 2015a; Carré et al., in press). Previous work has also found that more interdependence is associated with greater social anxiety (Hardin et al., 2006), whereas trait independence—although not measured by a self-construal scale—has had a strong positive association with dominance (e.g., Puffer, 2013). In light of the relatively small interaction effects observed, much larger sample sizes are needed to test whether each of these individual difference factors uniquely interacts with testosterone to predict aggressive behavior. Also, another related construct or higher order latent factor predicting these traits may explain why these individual differences moderate the association between testosterone and aggression.

An additional interesting finding of the current study was that interdependents showed a reversed association between basal testosterone and aggressive behavior. This reversal of the basal testosterone and aggression association is opposite from meta-analytic work suggesting positive, albeit small associations between basal testosterone and aggression in humans and larger positive associations in animals (Archer et al., 2005). However, recent research has revealed that the association between testosterone and antisocial or aggressive behavior is not so straightforward, as elevated testosterone is associated with fair bargaining behaviors (Eisenegger et al., 2010), honesty (Wibral et al., 2012), and reciprocity (Boksem et al., 2013).

Why might basal testosterone be associated with less aggression for those with interdependent self-construals? In addition to dominance (e.g., Mazur and Booth, 1998), testosterone is reputed to promote reward-seeking (Welker et al., 2015) and status-seeking (e.g., Josephs et al., 2006). These three possible psychological mechanisms may help explain the inverse testosterone-aggression association in interdependents. With respect to dominance and status seeking, behaving aggressively could be perceived as a possible way to decrease status rather than increase it, as interdependence is more characterized by adherence to social norms (e.g., Haberstroh et al., 2002). Thus, an interdependent person with high status seeking motivation—and potentially higher testosterone—would be less inclined to act aggressively. With respect to reward, previous literature suggests reactive aggression is often motivated by hedonic reward (Bushman et al., 2001; Chester and DeWall, 2016). Additionally, although animal and human literature suggests that testosterone can increase reward function and motivation (See Welker et al., 2015 for a review), perhaps more interdependent, high testosterone individuals are motivated toward different rewards than aggression such as preserving social connections or succeeding at self-control (Cross and Madson, 1997). Future research is needed to test motivations that explain this inverse relationship.

Our current study suggests self-construal and testosterone may not modulate aggressive behavior in women. However, an alternative explanation is that men are more likely to engage in costly aggressive behavior (Archer, 2004), such as through the PSAP, whereas women may be more prone to aggressing through other means, such as relational aggression (Crick, 1996). Another possibility is that higher measurement error in women's testosterone, as assessed by enzyme immunoassays, may have limited our ability to detect significant effects in women (Welker et al., 2016). Future research can more strongly test the role of testosterone and self-construal in women by using more varied measures of aggression and assessing testosterone through mass spectrometry, a highly accurate reference method for measuring testosterone (e.g., Soldin and Soldin, 2009).

This study adds to a growing literature showing that basal testosterone and testosterone dynamics are associated with social behavior,

particularly competitiveness, aggression and risk-taking (e.g., Mehta and Josephs, 2006; Apicella et al., 2014; Carré and McCormick, 2008; Carré et al., 2009, 2013, 2014; Geniole et al., 2011; Klimesmith et al., 2006; Ronay and von Hippel, 2010; Slatcher et al., 2011; Stanton et al., 2011). Future research can extend the current work through experimental manipulations of testosterone and self-construal. Several experimental manipulations of self-construal exist in the literature (e.g., Brewer and Gardner, 1996; Lee et al., 2000; Gardner et al., 1999). Future research would benefit from replicating the present research with an experimental manipulation of self-construal, and examining testosterone and aggression cross-culturally. Additionally, researchers are increasingly using pharmacological manipulations of testosterone to show causal evidence for the effects of testosterone on brain and behavior (e.g., Boksem et al., 2013; Goetz et al., 2014; Hermans et al., 2008). Using these pharmacological manipulations of testosterone and experimental manipulations of self-construal would provide causal evidence for the roles of these two variables in predicting aggression.

### 5.1. Conclusions

Altogether, the current research suggests that how men represent the self in relation to others influences the degree to which testosterone predicts men's aggression. These results might explain how testosterone predicts different types of behavior in social relationships and interactions, and why testosterone predicts aggressive behavior in some individuals but not others. Numerous mechanisms are thought to mediate the association between testosterone and aggression, such as reward-responsiveness and motivation (Welker et al., 2015 for a review), responsiveness to threats (e.g., Carré and Olmstead, 2015), and decreased empathy (e.g., Hermans et al., 2006). Overall, personality may influence the mediating psychological mechanism by which testosterone is associated with aggression. Uncovering the complex integration of social, personality, and neuroendocrine mechanisms of aggression is a prime goal in future research.

### Appendix A. Supplementary data

Supplementary data to this article can be found online at <http://dx.doi.org/10.1016/j.yhbeh.2016.10.014>.

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