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Adolescent Personality as Risk and Resiliency in the Testosterone–Externalizing Association

Kathleen W. Reardon, Kathrin Herzhoff, and Jennifer L. Tackett
University of Houston

Previous investigations of testosterone and externalizing behavior have provided mixed findings. We tested the hypothesis that self-regulatory personality moderates the testosterone–externalizing behavior association in adolescence. Parents reported on their 13- to 18-year-old (N = 106, M_{age} = 16.01, SD = 1.29) children's personalities and psychopathology. Testosterone was measured via drool samples. As hypothesized, personality moderated the testosterone–externalizing behavior association. High testosterone predicted higher levels of externalizing behaviors, but only for adolescents low in Agreeableness and Conscientiousness. Also, personality acted as a resiliency factor: high levels of Conscientiousness, in the presence of high testosterone, predicted *lower* levels of rule breaking. Results highlight how endogenous factors, such as personality, may interact with testosterone, and emphasize the relevance of including personality moderators in future research.

The relationship between the steroid hormone testosterone, which is produced by the hypothalamic–pituitary–gonadal axis and has androgenic effects, and various forms of externalizing behavior (especially aggression; Archer, 2006) has been an important area of empirical focus. However, especially in adolescence, the connection between testosterone and externalizing behavior appears to be complex, and results thus far have been mixed (Ramirez, 2003). In both youth and adults, higher levels of testosterone have been linked to aggression, social dominance, and conduct problems (Archer, 2006; van Bokhoven et al., 2006; Cashdan, 1995; Josephs, Newman, Brown, & Beer, 2003). Status-seeking behaviors have been linked to high testosterone, but motive pathways through which status seeking manifests (as dominance vs. prestige, for example; Cheng, Tracy, Foulsham, Kingstone, & Heinrich, 2013) may influence evidence for associations between testosterone and aggression. This influence is further supported by evidence that high testosterone is linked to aggression only in the context of high trait dominance (Carré, Putnam, & McCormick, 2009). There have also been numerous studies that find no connection between aggression and testosterone (Aluja & Garcia, 2007; Archer, Graham-Kevan, & Davies, 2005; Glenn, Raine, Schug, Gao, & Granger, 2011; van Goozen, Matthys, Cohen-Kettenis, Thijssen, & van Engeland, 1998; Granger et al., 2003), and some evidence for a negative association between these constructs (Book, Starzyk, & Quinsey, 2001). Meta-analyses support a weak, positive correlation between aggression and testosterone (Archer, 1991; Book et al., 2001; Ramirez, 2003; Rubinow & Schmidt, 1996), with minimal understanding regarding the differences that have emerged across studies.

Personality characteristics represent one domain with great potential for elucidating hormone–behavior associations (Gunnar, Kryzer, Van Ryzin, & Phillips, 2011; Phillips, Fox, & Gunnar, 2011; Shoal, Giancola, & Kirillova, 2003; Tackett, Kushner et al., 2014), but they have not yet been considered as a moderator of the testosterone–externalizing association. Personality traits are broadly defined and normally distributed in the population, offering a useful context for teasing apart individual differences in associations with biological markers (De Young et al., 2010). Specifically, self-regulatory personality traits (i.e., Agreeableness and Conscien-

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Requests for reprints should be sent to Kathleen W. Reardon, University of Houston, 126 Heyne Building, Houston, TX 77204. E-mail: kwreardon@uh.edu and Jennifer L. Tackett, University of Houston, 126 Heyne Building, Houston, TX 77204. E-mail: jltackett@uh.edu

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tiousness) show robust associations with externalizing behavior (Nigg, 2006; Tackett, 2006). Agreeableness describes a person's tendency to be altruistic and compliant, whereas Conscientiousness describes a person's tendency to be dutiful and self-disciplined (Costa & McCrae, 1992; Goldberg, 1993). They have been characterized as self-regulatory given their hierarchical relationship with the superordinate dispositional trait of effortful control (Jensen-Campbell et al., 2002; Markon, Krueger, & Watson, 2005; Tackett et al., 2012). Overall, Conscientiousness and Agreeableness have been negatively correlated with externalizing behavior (John, Caspi, Robins, Moffitt, & Stouthamer-Loeber, 1994; Miller, Lynam, & Jones, 2008), and low Conscientiousness and Agreeableness predict aggression and conduct-disordered behavior (Settles et al., 2012). Thus, the context of self-regulatory personality traits may help disentangle associations between testosterone and externalizing problems.

Although personality traits have not been specifically investigated in this domain, researchers have found evidence for important moderators of this hormone–behavior relationship (e.g., Book et al., 2001; Rubinow & Schmidt, 1996). One example of moderating factors with significant support in the literature is interpersonal relationships. Specifically, Rowe, Maughan, Worthman, Costello, and Angold (2004) demonstrated that the association between high testosterone and conduct disorder symptoms in adolescent boys was specific to boys with deviant peer group affiliations. In an extension of this work, Vermeersch, T'sjoen, Kaufman, and Vincke (2007) found a significant relationship between testosterone and nonaggressive risk taking. They found that boys with high levels of testosterone had friends who were more involved in risk-taking and that the influence of those friends contributed to higher risk-taking outcomes. These findings suggest that high testosterone was primarily associated with antisocial behavior in the context of high-risk relationships. It is also important to note that Rowe et al. (2004) further demonstrated a resiliency effect, such that for those boys with no evidence of deviant peer group associations, high testosterone was associated with leadership. High-risk contexts are another example of a potential moderating factor. For example, negative parenting behaviors can serve to increase traits such as frustration and impulsivity (Kiff, Lengua, & Zalewski, 2011). Because personality traits (intrapersonal characteristics) are implicated in the development and maintenance of interpersonal relationships, and in determining the effect of context, personality may serve a similar moderating role in the relationship between testosterone and externalizing behavior. This hypothesis is the focus of the present investigation.

In addition to testing this primary hypothesis, we wanted to examine whether testosterone shows differential associations with varying subtypes of externalizing problems and whether any of these associations were moderated by age. Classification of youth externalizing behavior often distinguishes between delinquent or rule-breaking behavior and aggressive behavior (Achenbach & Edelbrock, 1978; Burt, 2012; Stanger, Achenbach, & Verhulst, 1997; Tackett, Krueger, Sawyer, & Graetz, 2003). Rule-breaking behavior reflects acts such as running away from home, being truant, and vandalizing (Achenbach & Edelbrock, 1978), whereas aggression reflects behaviors such as fighting, bullying, and being cruel to others (Frick et al., 1993). These two subfactors have been differentiated in terms of biological causes (Lahey, Waldman, & McBurnett, 1999), developmental course (Moffitt, 1993), interpersonal correlates (Burt, Mikolajewski, & Larson, 2009), and etiologic influences (Tackett, Krueger, Iacono, & McGue, 2005). Additionally, personality correlates differentiate rule-breaking behavior and aggression, with Conscientiousness being more negatively related to rule-breaking than to aggression (Burt, 2012). Vermeersch et al. (2007) examined the impact of testosterone on both aggressive and nonaggressive risk-taking behaviors and found significant effects only for nonaggressive risk-taking behaviors, which suggests that the distinction between aggressive and delinquent behaviors may be important in this context. Thus, we were interested in whether behavioral heterogeneity within the externalizing domain may partially account for mixed or restricted findings.

There is a vast amount of hormonal, social, and maturational change taking place between the ages of 12 and 18 (Cameron, 2004), which implies that investigation of age as a possible moderator in the testosterone–externalizing behavior relationship is warranted. Specifically, the prevalence of overall externalizing disorders peaks in late adolescence (Moffitt, 1993; Moffitt, Caspi, Rutter, & Silva, 2001; Steinberg, 2008; Steinberg & Morris, 2001). Testosterone levels increase dramatically across adolescence (10-fold in males and 2- or 3-fold in females; Booth, Granger, Mazur, & Kivlighan, 2006), and the relationship between testosterone and aggression appears variable across stages of development (Ramirez, 2003). Finally, evidence has been found for mean-level age differences in

personality traits, including Conscientiousness and Agreeableness (Soto, John, Gosling, & Potter, 2011). Although we did not have specific hypotheses due to a lack of previous literature on age moderation in this context, we wanted to examine whether the nature of the testosterone–externalizing association (in the context of self-regulatory personality) differed across the age range of the current study.

The Current Study

The current study is the first to examine self-regulatory personality traits as moderators of the testosterone–externalizing behavior association in a mixed-gender, adolescent sample.

Specific study aims were as follows:

(1) To investigate whether self-regulatory personality traits (Agreeableness and Conscientiousness) would moderate the association between testosterone and externalizing problems in adolescence.
   (a) We hypothesized that, consistent with mixed findings in the literature, we would not observe a main effect of testosterone on externalizing problems.
   (b) We hypothesized that higher levels of testosterone would be associated with higher levels of externalizing behavior, but only for youth low in trait Agreeableness and Conscientiousness (i.e., only in the context of self-regulatory deficits—evidence for a risk effect).
   (c) Additionally, we hypothesized that higher levels of testosterone would be associated with lower levels of externalizing behavior, but only for youth high in trait Agreeableness and Conscientiousness (i.e., only in the context of self-regulatory strengths—evidence for a resiliency effect).
(2) To examine differential associations for subfactors of externalizing behavior: rule breaking and aggression.
(3) To conduct exploratory analyses to investigate the possibility for differential associations across age.

METHOD

Participants

Participants were 106 adolescents (56% female) between the ages of 13 and 18 years (M = 16.01, SD = 1.29). Data were collected from the adolescents' parents (96 mothers and 10 fathers). Informed assent or consent was provided by adolescents and parents at the beginning of the assessment. When reporting on their adolescent's race or ethnicity, 74.5% of parents identified their child as White, 6.6% as Asian Canadian, 4.7% as African Canadian, 0.9% as Latino or Latina, 0.9% as Pacific Islander, and 12.3% as other or multiracial. The average annual household income bracket was between 70,001 and 80,000 Canadian dollars, and most parents (87.7%) reported a college degree or higher. Adolescents were recruited as part of a follow-up assessment on a subsample of adolescent participants in a larger study on child personality and psychopathology at a large urban university. The response rate for participation in the follow-up assessment was 83% overall, with 72% participating in the laboratory and providing hormone samples (the remaining participants completed questionnaires by mail). This follow-up assessment is the only time point at which hormone data were collected from the longitudinal sample. The inclusion criterion for adolescents and parents was English language fluency. Exclusion criteria were a history of mental retardation, autism, or schizophrenia in the adolescent. Youth participants were compensated with a 25-dollar gift card, and their parents received 50 Canadian dollars for participating in the full laboratory visit and completing questionnaires at home. The university research ethics board approved all study methods and materials.

Measures

Externalizing behavior. Parents completed the Child Behavior Checklist for ages 6–18 (CBCL; Achenbach & Rescorla, 2001) about their adolescent's behavior. The CBCL 6–18 consists of 118 items that describe common problem behaviors. Respondents rated each item on a three-point scale ranging from 0 (*not true* (*as far as you know*)) to 2 (*very true or often true*) for the past 6 months. The Externalizing Behavior dimension (35 items) was the focus of the present study and showed good internal consistency in the present sample (Cronbach's α = .90). The Aggression (18 items) and Rule-Breaking (17 items) subscales each showed good internal consistency (Cronbach's α = .88 and .80, respectively). In addition, the Internalizing Behavior dimension (31 items) was used as a covariate in some analyses, and it also shows good

internal consistency in this sample (Cronbach's $\alpha = .86$).

Personality. Parents completed the Big Five Inventory (BFI; John, Donahue, & Kentle, 1991) about their adolescent's personality. The BFI is a 44-item questionnaire designed to measure the Big Five personality traits. In this study, we focused on the subscales measuring self-regulatory personality: Agreeableness (A; nine items) and Conscientiousness (C; nine items). Respondents rated each item on a five-point scale ranging from 1 (*disagree strongly*) to 5 (*agree strongly*). These two traits showed adequate internal consistency in the present sample (A Cronbach's $\alpha = .79$ and C Cronbach's $\alpha = .85$).

Testosterone. Saliva was collected using the passive-drool method. Participants were asked to drool through a sanitary straw into a 2-ml IBL vial. Testosterone levels were measured from a saliva sample collected approximately 30 min after the participants arrived in the laboratory.

Procedure

Among other questionnaires, the BFI was mailed to parents for completion and was returned during their laboratory visit. Parents completed the CBCL during the laboratory visit. All female participants were scheduled during the first 10 days of their menstrual cycle when hormone levels are most stable (Liening, Stanton, Saini, & Schultheiss, 2010). Given the diurnal variation of hormone levels (Kirschbaum & Hellhammer, 1994), all saliva samples were collected between noon and sundown (range: 11:59:40 to 19:15:50; M = 14:11:03, SD = 2.07.00). The exact time of sundown changes throughout the year, and so references were consulted to ensure visits were scheduled such that all saliva samples would be collected before sundown at that particular time of year. Participants were instructed not to eat or drink for 2 hr and not to smoke for 4 hr before their assessment. Upon arrival to the laboratory and once they had provided assent, participants rinsed their mouths with water and drank a small cup of water. After 30 min of sedentary activity (questionnaire completion), participants drooled through a sanitary straw into a 2-ml IBL vial. Samples were frozen at −20°C before being shipped on dry ice to Clemens Kirschbaum's laboratory at the Technical University of Dresden. Once there, samples were centrifuged at 3,000 rpm for 5 min and immunoassayed (IBL International, Hamburg, Germany). The average intra- and interassay coefficients for testosterone were below 8%.

RESULTS

Descriptive statistics and correlations for personality, psychopathology, testosterone, and age variables are presented in Table 1. When examining variable frequencies, no extreme values were detected. As is common for hormone variables, the distribution of testosterone values showed significant skewness (2.25), which was improved after log-transformation (−0.33). All statistical analyses were performed using Statistical Package for the Social Sciences version 21 (SPSS 21).

Broadband Externalizing Behavior

Moderation effects for Agreeableness and Conscientiousness were tested via hierarchical regression

TABLE 1
Correlation Coefficients and Descriptive Statistics

	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
1. Age	1.00							
2. Testosterone	0.15	1.00						
3. BFI Agreeableness	−0.03	−0.14	1.00					
4. BFI Conscientiousness	0.09	−0.19*	0.41***	1.00				
5. CBCL Externalizing Behavior	0.01	0.18	−0.18	−0.24*	1.00			
6. CBCL Internalizing Behavior	−0.07	0.00	0.08	−0.09	0.54***	1.00		
7. CBCL Rule-Breaking Behavior	0.08	−0.21*	−0.23*	−0.24*	0.87***	0.26**	1.00	
8. CBCL Aggressive Behavior	−0.05	0.14	−0.11	−0.20*	0.93***	0.66***	0.63***	1.00
M	16.01	1.01	3.89	3.39	6.58	6.73	2.43	4.15
SD	1.29	0.54	0.58	0.69	7.24	6.25	3.38	4.61

Note. Values displayed for testosterone are for the log-transformed variable. BFI = Big Five Inventory. CBCL = Child Behavior Checklist.
*$p < .05$; **$p < .01$; ***$p < .001$.

models. Prior to these analyses, we standardized all independent variables. In the examination of associations with overall Externalizing Behaviors (dependent variable [DV]), we first entered the covariates of youth age, gender, and time of waking (Step 1) followed by main effects for testosterone and either Agreeableness or Conscientiousness (Step 2). Next, we entered the corresponding interaction term (Testosterone × BFI trait) to investigate the presence of a significant moderation effect (Step 3). Next, we conducted these analyses in the same way, this time with CBCL Internalizing Behavior included as a covariate in Step 1. This was done to examine the specificity of the interaction effect between testosterone and either Agreeableness or Conscientiousness in predicting Externalizing Behavior scores (above and beyond general psychopathology). All analyses were repeated excluding the covariates of age, gender, and time of waking (as per Simmons, Nelson, & Simonsohn, 2011); all effects were robust and the pattern of results remained the same. Full details of these analyses are available from the first author. Additionally, we repeated all analyses using testosterone standardized within gender (Josephs, Guinn Sellers, Newman, & Mehta, 2006; Mehta & Josephs, 2010). The pattern of results was consistent with the results reported. Simple slope analyses were conducted according to Hayes's (2013) PROCESS modeling to probe the interactions which were found to be significant at personality trait levels one *SD* above and below the mean.

When not including Internalizing Behavior as a covariate in the analyses, Agreeableness significantly moderated the testosterone–externalizing relationship ($\beta = -0.22$, $t(99) = -2.25$, $p = .027$), but Conscientiousness did not ($\beta = -0.18$, $t(99) = -1.80$, $p = .075$; see Table 2). Simple slope analyses indicated that testosterone did not significantly predict Externalizing Behavior scores at Agreeableness levels one *SD* above ($b = -1.68$, $t(99) = -1.34$, $p = .184$) or below ($b = 1.66$, $t(99) = 1.53$, $p = .128$) the mean. When including Internalizing Behavior as a covariate in the analyses, the pattern of results for Agreeableness remained the same ($\beta = -0.22$, $t(98) = -2.77$, $p = .007$), and Conscientiousness emerged as a significant moderator of the testosterone–externalizing relationship, as well ($\beta = -0.25$, $t(98) = -3.13$, $p = .002$; see Table 2). Simple slope analyses indicated that testosterone positively predicted Externalizing Behavior scores at low ($b = 1.81$, $t(98) = 2.05$, $p = .043$) but not at high ($b = -1.55$, $t(98) = -1.51$, $p = .135$) levels of Agreeableness. Similarly, testosterone positively predicted Externalizing Behavior scores at low ($b = 2.07$, $t(98) = 2.21$, $p = .029$) but not at high ($b = -1.62$, $t(98) = -1.74$, $p = .086$) levels of Conscientiousness. Both of these findings indicate a risk effect for testosterone (see Figure 1).

Rule-Breaking Behavior Versus Aggressive Behavior

Next, we estimated models predicting Rule-Breaking Behavior scores (controlling for Aggressive Behavior) and Aggressive Behavior scores (controlling for Rule-Breaking Behavior) to address differential associations for subfactors of Externalizing Behavior. Otherwise, covariates were youth age, gender, and time of waking, and the same IVs were entered in the same steps as described previously. The results of these regressions were identical when including Internalizing Behavior as a covariate, so the reported results reflect the regressions without this covariate. Simple slope analyses were conducted to probe significant interaction effects. Conscientiousness significantly moderated the testosterone–Rule-Breaking Behavior relationship ($\beta = -0.23$, $t(98) = -3.06$, $p = .003$; see Table 2). Simple slope analyses indicated that testosterone negatively predicted Rule-Breaking Behavior scores at high ($b = -0.88$, $t(98) = -2.18$, $p = .032$) but not at low ($b = 0.67$, $t(98) = 1.68$, $p = .097$) levels of Conscientiousness, indicating a resiliency effect (see Figure 2). This moderation effect was not found for the prediction of Aggressive Behavior, and Agreeableness did not significantly moderate either Rule-Breaking or Aggression associations with testosterone (see Table 2).

Age Analyses

Finally, to address the question of differential associations across age, we tested three-way interactions for linear and quadratic effects of age. These analyses did not find significant interaction effects for age. We further examined whether age differences could be detected via Johnson–Neyman *regions of significance* analyses (Bauer & Curran, 2005; Hayes and Matthes, 2009; Johnson & Neyman, 1936; Kochanska, Kim, Barry, & Philibert, 2011; Preacher, Curran, & Bauer, 2006). According to Hayes and Matthes (2009), this method mathematically derives the points along the moderator variable (age, in this case) where the predictor term (BFI × Testosterone interaction term) transitions between statistically significant and nonsignificant, if such a point exists in the data. These points give a range of values along the continuum of the mod-

TABLE 2
Moderated Hierarchical Regression Analyses Predicting Child Behavior Checklist Externalizing Behavior, Rule-Breaking, and Aggressive Behavior Scores from Testosterone (Test) and Big Five Inventory (BFI) Self-Regulatory Personality Traits

		DV: Ext. Behavior					*DV: Ext. Behavior (covariate: Int. Behavior)*				
Step	*Variable*	*B*	SE_B	*95% CI*	R^2	*F*	*B*	SE_B	*95% CI*	R^2	*F*
		Model 1: BFI Agreeableness (BFIA)									
2	TEST	0.30	0.91	[−1.51, 2.11]	.08	1.76	0.44	0.76	[−1.06, 1.94]	.38	10.03***
	BFIA	−0.76	0.74	[−2.23, 0.71]			−1.19	0.62	[−2.41, 0.03]		
3	TEST × BFIA	−1.67*	0.74	[−3.14, −0.19]	.13	2.37*	−1.68**	0.61	[−2.88, −0.47]	.42	10.27***
		Model 2: BFI Conscientiousness (BFIC)									
2	TEST	0.12	0.90	[−1.66, 1.91]	.10	2.26	0.23	0.76	[−1.27, 1.72]	.37	9.79***
	BFIC	−1.32	0.72	[−2.74, 0.11]			−1.02	0.60	[−2.21, 0.18]		
3	TEST × BFIC	−1.30	0.72	[−2.72, 0.13]	.13	2.46*	−1.85**	0.59	[−3.02, −0.67]	.43	10.53***

		DV: RB Beh. (covariate: Agg. Beh.)					*DV: Agg. Beh. (covariate: RB Beh.)*				
Step	*Variable*	*B*	SE_B	*95% CI*	R^2	*F*	*B*	SE_B	*95% CI*	R^2	*F*
		Model 1: BFI Agreeableness (BFIA)									
2	TEST	−0.04	0.33	[−0.68, 0.61]	.47	14.77***	0.18	0.46	[−0.74, 1.09]	.42	12.16***
	BFIA	−0.35	0.26	[−0.88, 0.17]			0.14	0.38	[−0.61, 0.90]		
3	TEST × BFIA	−0.26	0.28	[−0.81, 0.29]	.48	12.78***	−0.39	0.39	[−1.16, 0.39]	.43	10.56***
		Model 2: BFI Conscientiousness (BFIC)									
2	TEST	−0.10	0.33	[−0.74, 0.55]	.47	14.59***	0.18	0.46	[−0.73, 1.10]	.43	12.20***
	BFIC	−0.29	0.26	[−0.81, 0.23]			−0.19	0.37	[−0.93, 0.55]		
3	TEST × BFIC	−0.78***	0.25	[−1.28, −0.27]	.52	14.91***	0.49	0.39	[−0.28, 1.26]	.43	10.75***

Note. Separate regression analyses were conducted for each BFI trait to examine the interaction terms between testosterone levels and adolescent personality traits. For both models, gender, age, and time of waking were entered in Step 1 as covariates. Model estimates are displayed for the new variables added at each step. BFI = Big Five Inventory. CBCL = Child Behavior Checklist. Ext. Behavior = Externalizing Behavior scale on the CBCL. Int. Behavior = Internalizing Behavior scale on the CBCL. RB Beh. = Rule-Breaking Behavior. R^2 coefficients represent the proportion of variance explained by the predictor variables in that step. *F* denotes significance of the regression model at each step. *B* = unstandardized regression coefficient. *SE* = standard error. *DV* = dependent variable. Values in brackets are 95% confidence intervals for the regression coefficients.
*$p < .05$; **$p < .01$; ***$p < .001$.

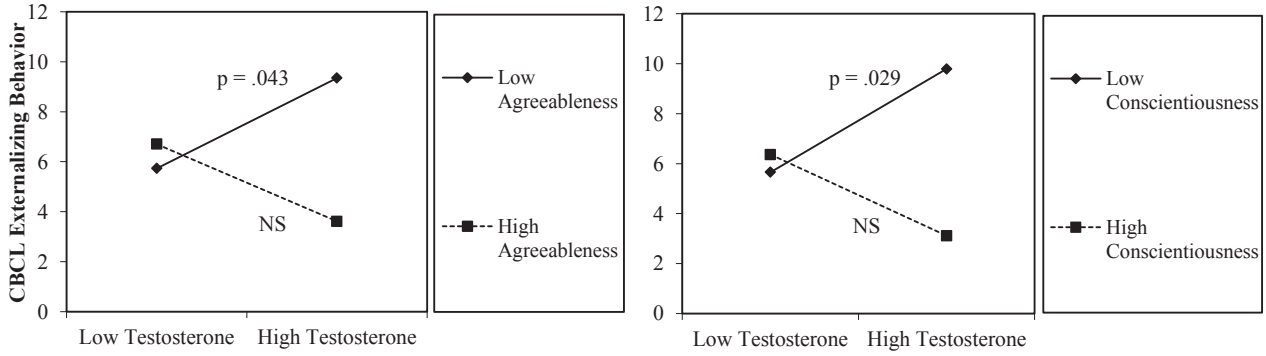

FIGURE 1 Interactions between testosterone and BFI Agreeableness (left panel) and BFI Conscientiousness (right panel) in predicting CBCL Externalizing Behavior, controlling for CBCL Internalizing Behavior. BFI = Big Five Inventory; CBCL = Child Behavior Checklist.

erator where the predictor term has a statistically significant effect. We used Hayes's PROCESS syntax (2013) to conduct these analyses, in order to determine whether there were points along the age continuum where the effect of the interaction term between personality and testosterone transitioned from nonsignificant to significant in predicting Externalizing Behavior scores. The results suggest that there was a region of significance along the age continuum for the interaction term between

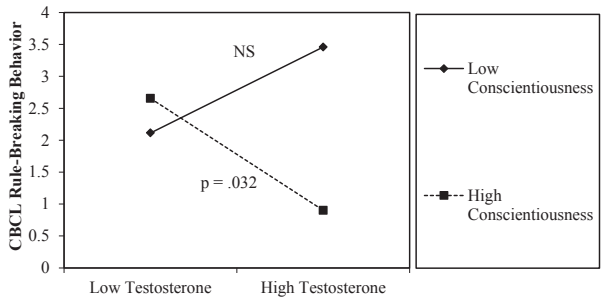

FIGURE 2 Interaction between testosterone and BFI Conscientiousness in predicting CBCL Rule-Breaking Behavior, controlling for CBCL Aggressive Behavior. BFI = Big Five Inventory; CBCL = Child Behavior Checklist.

testosterone and Agreeableness—the lower bound of the region of significance was 15.26 years and the upper bound was 17.54 years. That is, for any single age between the lower and upper bounds of the region of significance, the effect of the interaction term on predicting Externalizing Behavior scores was significant. There was no age-based region of significance for the interaction term between testosterone and Conscientiousness in predicting Externalizing Behavior scores.

DISCUSSION

The current investigation provides novel evidence that self-regulatory personality traits (i.e., Agreeableness and Conscientiousness) moderate the relationship between testosterone and adolescent externalizing behavior. Previous research has indicated that there is a weak positive correlation between testosterone and externalizing behaviors, but overall findings have been mixed (Book et al., 2001). Findings from this study suggest that the inclusion of self-regulatory personality may allow a more nuanced examination of testosterone–externalizing behavior associations. Specifically, in the context of low self-regulatory personality traits, testosterone acts as risk for externalizing behavior outcomes, as initially hypothesized.

Not surprisingly, there was no evidence for main effects of testosterone on the prediction of externalizing behaviors. Thus, when examining testosterone–externalizing associations without attention to self-regulatory personality, these differential effects are masked. When including personality variables, however, significant interaction effects were found for both Agreeableness and Conscientiousness predicting unique variance in externalizing problems (controlling for shared variance with internalizing problems). These findings are largely consistent with evidence that high testosterone increases risk for externalizing problems in the context of high-risk relationships (Rowe et al., 2004; Ryan et al., 2013; Vermeersch et al., 2007), extending this finding to intrapersonal self-regulatory deficits.

A particularly provocative aspect of the current findings is the parallel pattern of effects we find for self-regulatory personality moderators to previous findings for interpersonal relationship moderators, such as peer group influences (Rowe et al., 2004; Vermeersch et al., 2007). One explanation for these similar findings is that personality and peer group association are two independent influences that interact with testosterone to impact behavioral outcomes. An alternative explanation is that the influence of peer group association is largely reflective of self-regulatory personality traits. This latter hypothesis is supported by evidence that personality influences later peer group selection, but many studies investigating peer group influence neglect to consider the possible role of personality. In particular, hyperactivity and fearlessness, which can be understood as self-regulatory deficits, predicted sooner deviant peer group association and future antisocial behavior (Lacourse et al., 2006). Self-control has also been found to be a significant longitudinal predictor of association with deviant peers, such that youths with low self-control select into delinquent peer groups (Chapple, 2005). This evidence suggests that, among those individuals who have intrapersonal self-regulatory deficits, there may be a propensity for deviant peer group association and a higher risk for antisocial behavior. Most studies focus either on the influence of peer group or on the influence of personality on delinquent behavior, but do not account for both influences simultaneously. Research better positioned to disentangle causal effects and designed to directly compare these two competing hypotheses is a critical future direction.

Although these results are in line with other investigations of hormone–behavior relationships, these results are novel and the mechanism by which self-regulatory personality exerts its influence is somewhat unclear. Because personality traits are broadly distributed in the general population, they may serve to stratify normative samples and allow narrower focus on those individuals for which these relationships are most robust (De Young & Clark, 2012; Tackett, Kushner, De Fruyt, & Mervielde, 2013). For example, high testosterone has been shown to lead to status-seeking behaviors, but this may be accomplished either through domi-

nance or through prestige (Cheng et al., 2013). It may be that self-regulatory personality traits are a factor that differentiates these methods; indeed, those who typically employ dominance are described as aggressive, narcissistic, and Machiavellian, and those who employ prestige are described as socially accepted, agreeable, and conscientious (Cheng et al., 2013). Carré et al. (2009) found a relationship between high testosterone and aggression, but this relationship was dependent on trait dominance. Similarly, we find a relationship between high testosterone and externalizing behavior, but this relationship is dependent on self-regulatory personality traits. Testosterone decreases the coupling between the amygdala and orbito-frontal cortex (OFC), which may lead to higher threat reactivity and poor impulse control (Spielberg et al., 2014). Research bridging cognitive neuroscience and behavioral endocrinology found that testosterone increases aggression by reducing the OFC's capacity for impulse control and self-regulation (Mehta & Beer, 2009). Thus, it may be that low self-regulatory personality traits serve as an index of the underlying neurological functioning associated with high testosterone.

Regarding unique variance in behavioral subfactors of externalizing problems, this study does demonstrate that testosterone interacted with Conscientiousness to predict unique variance in rule-breaking behaviors, although no similar pattern emerged for unique variance in aggression. Importantly, these results provide the first extension of evidence that testosterone buffers against externalizing behaviors in more adaptive interpersonal contexts (Booth, Johnson, Granger, Crouter, & McHale, 2003; Rowe et al., 2004) by extending this finding to intrapersonal self-regulatory strengths. This is consistent with findings that self-control reduces the effects of multiple risk factors on externalizing behaviors such as substance use (Wills, Ainette, Stoolmiller, Gibbons, & Shinar, 2008). Our results are also generally consistent with the study by Vermeersch et al. (2007), who found that testosterone levels were only a significant predictor of non-aggressive risk-taking behavior, and found no similar pattern of results for the prediction of aggressive risk-taking. It is important to note that examination of externalizing behavior subtypes focused on specific variance, after accounting for general variance in externalizing behavior. Thus, such analyses examine a much more restricted range of potential variance and also covary out the more generalized variance examined for the broader Externalizing Behavior construct. Thus, it is not expected that associations found for generalized Externalizing Behavior would replicate for specific unique variance in each subtype. In addition, Conscientiousness has been specifically linked with rule-breaking behaviors, relative to aggression, in previous studies (Burt, 2012). Rule-breaking behaviors in particular may have more to do with impulsivity and related traits than with components of the personality trait of Agreeableness (Burt & Donnellan, 2008), which may explain why Agreeableness dropped out when examining subfactors compared to broadband externalizing behavior. Any such interpretations must be tentative in the current sample, however.

Regarding the potential effects of age, no evidence was found for linear or quadratic effects via three-way interactions. However, additional analyses aimed to probe potential regions of significance for age suggested that the moderating effect of Agreeableness was only significant for adolescents between ages 15.26 and 17.54 in the present study. These findings can be interpreted in the context of increased prevalence rates of both testosterone and externalizing problems across adolescence, which may offer maximal power for detecting such associations. In addition, older adolescents experience greater autonomy than do younger adolescents (Steinberg & Silverberg, 1986), which may strengthen associations between an individual's personality and behavioral outcomes in mid-late adolescence. No regions of significance were detected for Conscientiousness moderation.

The present study has significant implications for the treatment of externalizing problems. Other studies have found that early intervention programs can have a profound beneficial impact on hormone levels (Cicchetti, Rogosch, Toth, & Sturge-Apple, 2011). This implies that early intervention with externalizing problems could impact testosterone levels, and indeed, this was found to be the case in a large longitudinal study, such that early intervention was linked to a later decrease in testosterone reactivity to social provocation (Carré, Iselin, Welker, Hariri, & Dodge, 2014). The present study provides evidence that testosterone only acts as a risk factor in the context of low self-regulatory personality, however, and that it may in fact be beneficial in the context of adaptive self-regulation. This suggests that an intervention aimed at increasing self-regulatory skills may be particularly beneficial for children with high testosterone. This may serve to turn a potential risk factor into a strength. Through early intervention aimed at reducing externalizing behavior and testosterone or aimed at

increasing self-regulation, there are important clinical implications for the moderating role of personality in the testosterone–externalizing behavior relationship.

Limitations and Future Directions

The sample used in the present study included a wide age range of adolescents, which allowed for preliminary examination of possible age effects; however, this age range in combination with the sample size may have limited the ability to detect significant linear or quadratic age moderation of these effects. The follow-up analyses for Johnson–Neyman regions of significance testing did indicate that these relationships may show important changes across adolescent development. Thus, future research with larger sample sizes or longitudinal data on participants across phases of adolescent development should help to clarify remaining developmental questions about how moderators influence testosterone–externalizing behavior associations. The analysis of a single point-in-time measurement of the variables of interest represents a limitation of the present study, as it constrains the conclusions we can draw. We are not, for example, able to examine questions such as the role of early experiences or early behavior in shaping the variable relationships we find. Additionally, only parent-report personality and psychopathology variables were utilized in the present investigation, and this represents an important limitation that could be remedied by future studies by including information from multiple informants, especially youth self-reports. However, previous research on the interaction between individual differences and hormones predicting psychopathology found that parent-report variables were more robustly related to youth hormone variables (Tackett, Herzhoff, Harden, Page-Gould, & Josephs, 2014), which provides validity for the current approach.

Finally, the sample size of 106 adolescents represents a limitation of the present study. Data collection was limited to a restricted pool of participants as it was collected as part of a longitudinal study, but a future investigation with a larger sample size could provide increased power to investigate the nuances of the relationships uncovered in the present study.

An exciting direction for future research is the exploration of interindividual differences versus intraindividual change in testosterone (Granger, Shirtcliff, Booth, Kivlighan, & Schwartz, 2004; Kivlighan, Granger, & Booth, 2005). Single measurements of testosterone are widely used in behavior research and supported by large correlations among single-sample testosterone measurements across 7–8 weeks (Dabbs, 1990). Nonetheless, state levels of testosterone show fluctuations in response to environmental variables such as social threat and challenge (Maner, Miller, Schmidt, & Eckel, 2008), which means that single-sample measurements may be vulnerable to similar fluctuations. In addition, testosterone varies diurnally, and a single sample means that this variation is not detectable. Thus, future studies collecting multiple hormone samples from the same individuals will be better positioned to determine whether diurnal fluctuation plays a role in these associations and whether state versus trait testosterone levels are differentially associated with externalizing problems in the context of self-regulatory personality.

Additionally, although both risk and resiliency effects were not identified for a single predictor (i.e., Externalizing Behavior), the pattern of results was the same for all significant interactions. Thus, future studies with large samples in circumscribed age ranges should determine whether both risk and resiliency effects for testosterone could be replicated in the prediction of Externalizing Behavior. Furthermore, another interesting future direction for a study with a bigger sample is breaking down our analyses at the higher-order personality domain level into the lower-order personality facet level to illuminate which more specific aspects of Agreeableness and Conscientiousness drive the pattern of results found in this study. For example, it is possible that Agreeableness aspects related to prosociality rather than self-regulation are driving the resiliency effect that we found and the proposed facet-level analyses would illuminate this issue.

CONCLUSION

Taken together, these results demonstrate that adolescent personality is an important moderating variable in the relationship between testosterone and externalizing behaviors. Specifically, high levels of testosterone predicted high levels of externalizing problems, but only for youth with self-regulatory deficits (i.e., low Agreeableness and low Conscientiousness). Furthermore, high levels of testosterone predicted *low* levels of rule-breaking behaviors in the context of self-regulatory strengths (i.e., high Conscientiousness). Thus, high testosterone appears to serve as both risk and resiliency for different

types of externalizing behaviors, depending on a youth's level of self-regulatory personality traits. Overall, this work highlights the relevance of self-regulatory personality when examining the link between testosterone and externalizing behavior outcomes.

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