Research Report

Guns, Testosterone, and Aggression

An Experimental Test of a Mediational Hypothesis

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ABSTRACT—***We tested whether interacting with a gun increased testosterone levels and later aggressive behavior. Thirty male college students provided a saliva sample (for testosterone assay), interacted with either a gun or a children's toy for 15 min, and then provided another saliva sample. Next, subjects added as much hot sauce as they wanted to a cup of water they believed another subject would have to drink. Males who interacted with the gun showed significantly greater increases in testosterone and added more hot sauce to the water than did those who interacted with the children's toy. Moreover, increases in testosterone partially mediated the effects of interacting with the gun on this aggressive behavior.***

Substantial evidence suggests that aggression can be increased by the presence of weapons in the environment and by the hormone testosterone. Several studies show that the presence of aggressive environmental cues such as weapons can increase the accessibility of hostile, aggressive thoughts and lead to more aggressive behavior (Anderson, Benjamin, & Bartholow, 1998; Bartholow, Anderson, Carnagey, & Benjamin, 2005; Berkowitz & LePage, 1967; Bettencourt & Kernahan, 1997; Killias & Haas, 2002). Regarding testosterone, in animal species ranging from chickens to monkeys, the injection of this hormone increases aggressiveness and social dominance behavior, regardless of whether the animals are males or females (Ellis, 1986); in humans, however, the results are more mixed, with many laboratory and field studies revealing strong positive relations between testosterone and levels of restlessness, tenseness, and tendency toward violence (Archer, 1994; Campbell, Muncer, & Odber, 1997; Dabbs, Carr, Frady, & Riad, 1995; Dabbs, Jurkovic, & Frady, 1991) and other studies failing to replicate such effects (Archer, 1991; Archer, Birring, & Wu, 1998; O'Connor, Archer, Hair, & Wu, 2001; Rowe, Maughan, Worthman, Costello, & Angold, 2004).

Surprisingly, we were unable to find any studies that examined whether testosterone and the presence of a weapon might work together to increase aggressive behavior. Perhaps the presence of a stimulus such as a gun triggers increases in testosterone levels, which in turn increase aggressive behavior. Such a chain of events would be predicted by the *challenge hypothesis* developed by Wingfield, Hegner, Dufty, and Ball (1990) to explain aggressive behavior in male pair-bonded birds. According to this hypothesis, testosterone rises in response to situational cues that represent either a threat to a male's status or a signal that competition with other males is imminent; such increases in testosterone then facilitate whatever competitive behaviors (including potentially aggressive responses) are necessary for meeting the challenge. The challenge hypothesis has been supported by studies across a wide range of vertebrate species (Cavigelli & Pereira, 2000; Ferree, Wikelski, & Anderson, 2004; Hirschenhauser, Taborsky, Oliveira, Canario, & Oliveira, 2004; Muller & Wrangham, 2004); most studies in humans have focused on how males' testosterone levels rise and fall depending on success or failure in competitions (Archer, 1991; Booth, Shelley, Mazur, Tharp, & Kittok, 1989; Gladue, Boechler, & McCaul, 1989; Mazur, Booth, & Dabbs, 1992; Mazur & Lamb, 1980) or in response to insults (Cohen, Nisbett, Bowdle, & Schwarz, 1996; see Archer, 2006, for a review of the applicability of the challenge hypothesis to humans).

In this study, we examined whether the presence of a gun (vs. a control object) might act as a stimulus signaling competition and a threat to status; if so, according to the challenge hypothesis, it should cause increases in males' testosterone levels, which in turn should increase their aggressive behavior. We assessed males' testosterone levels both before and after interacting with a gun or a children's toy; to measure aggression, we adapted a method developed by Lieberman, Solomon, Greenberg, and

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McGregor (1999) that gives subjects the opportunity to anonymously put hot sauce in a cup of water that they believe another person will have to drink. We hypothesized that males who interacted with the gun would show both a greater increase in testosterone levels and more aggression than would males who interacted with the children's toy. We also hypothesized that changes in testosterone levels would be correlated with aggression levels and would indeed mediate the effects of interacting with a gun on later aggressive behavior.

METHOD

Subjects

Subjects were 30 male college students (age range: 18–22) who received extra course credit or a small monetary reward for their participation. All subjects were run during the afternoon or early evening.

Procedure and Materials

When recruited, subjects were informed that the study would examine taste sensitivity in males and that they would therefore need to provide saliva for hormone analysis; subjects were asked not to eat, drink, smoke, or brush their teeth for 1 hr prior to testing in order to minimize impurities in the saliva samples. When subjects arrived at the lab, a female experimenter confirmed that the subjects had indeed followed these instructions before she administered consent procedures. Next, participants provided an approximately 6-ml sample of saliva by spitting into a cup; this saliva was used to assess baseline, or Time 1, testosterone levels.

All subjects were then led into a room containing a television, a chair, and a table with an object and some paper on it. For experimental subjects, the object was a pellet gun identical in size, shape, and feel to a Desert Eagle automatic handgun; for control subjects, the object was the children's game Mouse Trap™. Subjects were told that the study was investigating whether taste sensitivity was associated with the attention to detail required for creating instructions concerning the object. Subjects were therefore asked to spend 15 min handling the object and writing a set of instructions about how to assemble and disassemble it; a drawing of the object was also provided for subjects to label the object's parts. The handgun and children's game were similar in number and complexity of parts.

After 15 min, the experimenter reentered the room, asked the subject to stop working on the instructions, and obtained a Time 2 saliva sample from the subject. The subject was told he would next perform the taste-sensitivity portion of the study. He was given a cup filled with 85 g of water and a single drop of Frank's Red Hot Sauce. The subject was told that the sample had been prepared by a previous subject, was instructed to take a sip of the sample, and was then asked to rate the taste of the sample on a scale provided.

The experimenter left and then returned with a tray containing a cup of 85 g of water, a nearly full bottle of Frank's Red Hot Sauce, and a lid. The subject was asked to prepare a sample for the next subject by placing as much hot sauce in the water as he wanted. He was assured that neither the person who drank it nor the experimenter would know how much hot sauce he had put in the water, as the lid was to be put on the cup after the hot sauce was added. The experimenter then left the room, and the subject signaled when he was finished adding the hot sauce. (Throughout this process, the gun or the game remained in the room.) The cup was then removed from the room, and the experimenter weighed it again to obtain a measure of the amount of hot sauce, in grams, the subject had added to the water. This served as our primary measure of aggression (see Lieberman et al., 1999).

Because of the potentially arousing nature of the experiment, we wanted to ensure that all subjects were reasonably calm when they left the lab. Therefore, all subjects next watched a relaxing video of nature scenes and classical music. Given that subjects had been deceived, we next debriefed them, emphasizing that they should not feel badly about any aggressive behavior they exhibited. Interestingly, several subjects were disappointed when told that the sample of hot sauce and water they had prepared would not actually be given to the next subject. No subjects expressed suspicion as to the true nature of the study.

Testosterone Levels

Time 1 and Time 2 saliva samples were stored for 24 hr at room temperature, centrifuged, and then frozen at −20 °C until the time of the assay (Erikkson & Von Der Pahlen, 2002). The samples were then brought to room temperature, transferred to Eppendorf tubes, centrifuged for 15 min at 3,000 rpm to remove debris, and then assayed in duplicate using a commercially available microwell kit for testosterone level (Salimetrics, LLC, State College, PA). All samples were assayed in house in a single batch using a standard radioimmunoassay (RIA) procedure under the supervision of an experienced RIA technician; at both Time 1 and Time 2, the duplicates were averaged to yield our measures of testosterone level. The intra-assay coefficient of variation for subjects was 5.3%, and the sensitivity of the assay was less than 1.5 pg/ml from zero for men. Mean Time 1 and Time 2 testosterone levels were 222.59 pg/ml (SD = 97.17) and 253.92 pg/ml (SD = 98.32), respectively. We subtracted each subject's Time 1 level from his Time 2 level to obtain a measure of change in testosterone.

RESULTS

Our first hypothesis was confirmed: Subjects who interacted with the handgun showed a greater increase in testosterone from Time 1 to Time 2 (mean change = 62.05 pg/ml, SD = 48.86) than did those who interacted with the children's game (mean change = 0.68 pg/ml, SD = 28.57), $t(28) = -4.20$, $p_{rep} = .99$, $d = 1.53$. Thus, interacting with the gun increased testosterone levels.

Our second hypothesis was also confirmed: Subjects who interacted with the gun added more hot sauce to the water (M = 13.61 g, SD = 8.35) than did those who interacted with the children's toy (M = 4.23 g, SD = 2.62), $t(28) = -4.16$, p_{rep} = .99, d = 1.52. Thus, interacting with the gun increased aggressive behavior.

Our third hypothesis was also confirmed: The amount of hot sauce placed in the cup was positively correlated with changes in testosterone level ($r = .64$, $p_{rep} = .99$; $R^2 = .41$). Given that all three of Baron and Kenny's (1986) prerequisites for a mediational model were met, we next examined whether the size of the association between the predictor variable (i.e., gun vs. game) and the outcome variable (i.e., grams of hot sauce added) diminished once the effects of the purported mediating variable (i.e., changes in testosterone) were controlled. Indeed, the size of the correlation between group membership (experimental vs. control) and aggression dropped from $r = -.62$ ($p_{rep} = .99$) to $pr = -.36$ ($p_{rep} = .91$) after controlling for changes in testosterone. Finally, to more stringently test our mediational hypothesis, we computed Sobel's (1982) test for mediation, using the Web site developed by Preacher and Leonardelli (2001). As before, the evidence suggested that the effect of guns on aggression was significantly mediated by changes in testosterone levels, Sobel's test = 2.09, $p_{rep} = .93$.

DISCUSSION

Past research shows that both testosterone and exposure to guns are associated with aggressive behavior, but no studies, to our knowledge, have examined how the two factors might work together. The present results demonstrated that males who interacted with a gun showed a greater increase in testosterone levels and more aggressive behavior than did males who interacted with a children's toy. Mediational analyses suggested that part of the reason that guns increase aggression is that they cause increases in testosterone levels.

Such findings not only are consistent with the challenge hypothesis (Wingfield et al., 1990), but also provide new support for it both by examining a new type of "challenging" stimulus and by assessing later aggressive behavior. Additionally, the results provide evidence against some interpretations suggesting that experimental effects of guns on aggression are due to subtle demand characteristics. That is, it seems unlikely that subtle experimenter pressures could significantly increase subjects' testosterone levels; instead, it seems more reasonable to believe that the presence of the gun had this effect.

Future research could explore a variety of avenues for correcting some of the limitations of the present study. For example, would females' biological and behavioral responses to guns be similar to males'? Perhaps they would, as other female animals act more aggressively when injected with testosterone (Ellis, 1986). But perhaps they would not, as the types of evolutionary challenges faced by ancestral females were different from those faced by males, and thus females may react to guns differently than males. Another topic worthy of further study concerns the fact that subjects in this study only had the opportunity to aggress in an anonymous, rather indirect fashion against an unknown individual. Would the same pattern of results hold if the aggression was directed against a particular individual, or if there was a possibility of retribution from the victim? Finally, would past experience with guns moderate these effects? That is, would individuals who frequently handle guns (such as hunters or soldiers) respond similarly to those with little or no experience with weapons? Previous research (Bartholow et al., 2005) suggests that this may be the case, but a link with testosterone has yet to be established.

In sum, the present study replicates past research showing that exposure to guns may increase later interpersonal aggression, but further demonstrates that, at least for males, it does so in part by increasing testosterone levels. Such findings raise many of the usual questions about whether the presence of guns in modern society contributes to violent behavior. Although our study is clearly far from definitive, its results suggest that guns may indeed increase aggressiveness partially via changes in the hormone testosterone.

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