Testosterone and Cortisol in Coalitional Competition

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by

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The undersigned, have examined the thesis entitled

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and hereby certify that, in their opinion, it is worthy of acceptance.

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Abstract

Fourteen teams of three young men competed in within-group and between-group videogame tournaments. Salivary cortisol and testosterone levels were assessed twice before and twice after each tournament, along with intelligence, anxiety, mood, personality and social variables. Men high on self-reported social leadership traits and who ranked first or second across both teams showed increased testosterone following the between-group competition and increased cortisol following the within-group competition. Low ranking men on winning teams did not show an increase in testosterone, but high ranking men on losing teams did. Although a between-group team effect did not emerge for testosterone, there were consistent differences in hormone response comparing the between- and within-group matches; testosterone was related to performance in the between-group match and cortisol in the within-group match. Implications are discussed in terms of men's competitive responses when competing against teammates compared to when competing against an unfamiliar team.

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Chapter 1: Introduction

According to the Entertainment Software Association (2008), annual videogame sales in the United States have grown from $2.6 billion in 1994 to $9.5 billion in 2007; with 67% of heads of households playing videogames and 42% of Americans planning to buy videogames in 2006. Online games that incorporate a group-level social component have an unprecedented level of player commitment. Yee (2006) surveyed 30,000 online gamers from 2000-2003 and found that they spend an average of 22 hours per week playing their chosen game, and 9% reported spending more than 40 hours per week. It is clear that substantial amounts of time and money are spent on videogames, though the underlying sources of appeal are not well understood.

A life history perspective from evolutionary biology may provide clues to the appeal of videogames, especially for younger men. Life history theory and research is focused on the evolution and expression of the timing of key developmental events (Roff, 1992) such as reproductive maturation (Elias, 2004). From this perspective, competition over resources and mates should peak in young adulthood; therefore this period should be marked by the highest levels of conflict. Palmer (1993) proposed that group-level competition, such as sports, reflect a proximate motivational mechanism that increases the individual's competitiveness, namely motivation to practice group-on-group competition (Geary, Byrd-Craven, Hoard, Vigil & Numtee, 2003). My hypothesis is that the appeal of multiplayer videogames is in simulating competition and a corresponding triggering of an evolved motivational disposition for males to engage in group-level competition.

The majority of research on videogames is focused on the relation between game play and aggression (e.g., Bartholow, Bushman, Sestir, 2006; Kirsch, 2003; Anderson & Dill, 2000), but this is not the focus here. Rather, I focus on the competitive motivation as expressed during the playing of videogames. A large body of literature has focused on understanding the role of testosterone and cortisol in competitive motivation (for reviews Salvador, 2005; Archer, 2006). In general, when challenged, male's testosterone increases, and depending on the outcome and the importance of the event for the male remains high for winners and drops for losers (Mazur,1985; Wingfield, Hegner, Dufty, Ball, 1990). Currently there are no explicit tests of coalitional competition, as related to testosterone and cortisol among males, however there is evidence that competitive motivation for males differs when competing in dyads or as teams (Salvador, Simon, Suay & Llorens, 1987; Mazur, Booth & Dabbs, 1992; Kivilghan, Granger & Booth, 2005; Wagner & Flinn, 2002). Moreover, evolutionary models propose that humans evolved in the context of group-on-group competition (See Alexander, 1990; Flinn, Geary & Ward, 2005). One corresponding prediction is that there may be evolved behavioral and motivational dispositions that could result in changes in testosterone and cortisol when engaged in group-level competition, and in simulating that competition (Geary, 2005).

Evolutionary Context

Life History Theory

Life History Theory is concerned with understanding the factors that produce variation in the timing of key developmental events (e.g., age of sexual maturity, growth rate and the pace of reproduction) found within and between species. The mechanisms that underlie life history variations are considered trade-offs in the expression of competing phenotypes (Roff, 1992). A common life history trade-off is whether a species reaches sexual maturity rapidly and quickly produces many, lower quality, offspring, or matures more slowly and invests in a smaller number of higher quality offspring. All else being equal, selection will favor rapid development and reproduction, because of the extreme reproductive cost of dying before maturity. However, when juvenile mortality is low, there can be benefits to delaying reproduction to accrue reproductive potential (Charnov, 1993). Reproductive potential describes resources that could be used enhance the individuals' reproductive prospects in adulthood as related to enhanced mate competition, parenting ability, or survival ability.

For example, there is a difference in the life history development of different populations of guppies (*Poecilia reticulala)*, as related to variation in the number and type of predators. In populations where predation of adults is high, individuals reproduce at an earlier age, have more offspring of lesser size, and have shorter interbrood intervals. Conversely, in populations where predation for offspring is higher and adult mortality is lower, individuals attained larger size and spread reproduction over more numerous reproductive cycles (Reznick & Ender, 1982).

A species life history is heavily influenced by survival prospects, but also other factors such as competition with conspecifics (i.e., members of the same species). For example, similar to life history trade-offs mentioned above for guppies, there are trade-offs between survival and reproduction. Male guppies (*Poecilia reticulala)* tend to be more colorful than female guppies. Females, on average, prefer more brightly colored males, because coloration of males serves as an indication of health status. However, brightly colored males incur greater predation due to increased conspicuousness (Godin & McDonough, 2002). In this species, predators select against bright colors while the female preference for brightly colored males maintains the trait in the population, the result is that less colorful males may survive longer, but at a cost to mating success (Millar, Reznick, Kinnison & Hedry, 2006).

Sexual Selection

Darwin (1871) considered natural selection to result in the evolution of traits that covaried with an individual's fitness, through enhanced survivorship. Sexual selection, in contrast, refers to the evolution of traits that can sometimes reduce survivorship and concurrently enhance fitness through competition over mates (e.g., intrasexual competition) and mate choice (e.g., intersexual competition), as illustrated with guppies above.

The dynamics of sexual selection arise from differential investment between the sexes in parenting (Trivers, 1972). Investing in offspring necessarily reduces the time and energy an individual can spend on maintaining their own physical condition and finding additional mates. Thus, the cost of investing in offspring reduces the individual's capacity for future reproduction. However, the costs and benefits are not the same for the two sexes. Sexual reproduction in mammals necessitates some initial obligatory investment by females (e.g., carrying the offspring and post-partum feeding) that biases them toward continued investment. When additional investment from males is not necessary for offspring survival, males are free to pursue mating opportunities. As a result, in 95% of mammalian species, paternal investment is absent (Clutton-Brock, 1991).

In general, the parent that accrues the highest cost becomes the choosy sex, whereas the parent that invests less in parenting invests more in mating effort; specifically with competition with others of the same sex or access to mates or other resources that influence this access. However, role reversals do occur in nature and support parental investment hypotheses (Trivers, 1972). For example, Gynne (1984) demonstrated the dynamics of sexual selection in relation to resource provision among the mormon cricket (*Anabrus simplex*); actually a species of katydid. In this species, the male produces a substantial (i.e., 30% of his body mass) spermataphore which contains nutrients the female requires for egg laying. When food sources are abundant, the males can produce many spermataphores and can therefore mate many times. Under these conditions there is an abundance of males with a spermataphore, making the female the choosy sex. However, when food sources are scarce, the males' spermataphore becomes the limiting resource. Under these conditions, males become choosy, and will reject all but the heaviest females; a female's weight is indicative of egg laying capacity (Gwynne, 1981).

Intrasexual Competition

For mammals, intrasexual competition is most commonly manifested as male-male competition involving direct physical threat and aggression (Andersson, 1994; Clutton-Brock, 1989). Physical one-on-one male-male competition occurs when individual males can monopolize more than one female and commonly results in body-size dimorphism, and among other things, a lengthening of the males juvenile period to allow for the accrual of reproductive potential (e.g., to become larger). For example, pinnipeds or seals breed and raise young on land, or on floating ice, and females typically congregate and form groups that can be defended by a single male. Under these conditions, the potential for male-male competition and polygamy can evolve. In these species, large aggressive males control harems. As a result, across species of *pinnipedia*, harem size serves as an index of body-size dimorphism (Lindenfors, Tullber, & Biuw 2002), with larger harem sizes associated with larger sex differences, favoring males, in physical size.

Intrasexual Competition and Cooperation

In more complex social systems, intrasexual competition can take the form of alliances or coalitions. The potential to evolve a bias to form coalitions depends in part on which sex remains in their natal group. The sex that stays in their natal group is the philopatric sex and lives among kin. Relations among kin tend toward altruism rather than strict give and take reciprocity (Trivers, 1971); this is because kin have a mutual self interest due to their shared genes (Hamilton, 1964). For example, Belding's ground squirrel (*Spermophilus beldingi*) lives in matrilineal kin groups and are known for giving alarm calls that warn others of danger, but are costly in that they alert predators to the whereabouts of the caller. Sherman (1977) showed that alarm calls were almost exclusively given by adult females with nearby kin, thereby counterbalancing the potential cost of giving an alarm call with increasing the chances of her kin getting away safely.

As found with Belding's ground squirrel, many species of Old World monkey (i.e., African and Asian) are female philopatric. Female alliances in these primates tend to form in the context of direct competition for clumped resources (i.e. fruit trees) and are therefore of vital importance to their reproductive success (Wrangham, 1980). One result of the increased social complexity of monkeys is that in female philopatric species, female kin not only help each other, but form complex matrilineal dominance hierarchies that compete with other matrilines for control of core resources (Silk, 2002).

Male philopatry is much less common in primates, but includes our two closest relatives, chimpanzees (*Pan troglodyte*s) and bonobos (*Pan paniscus*). Chimpanzees tend to form coalitions in the context of defending a territory which encompasses the sub-territories of unrelated adult females (Wrangham, 1999). Chimpanzees' dominance hierarchies are male biased. Higher ranking males have priority access to estrous females, rather than to resources.

One result of male-philopatry is that male-male competition also occurs between groups, as well as within groups. Chimpanzee territoriality is intense, intergroup relations between neighboring communities are tense and hostile (Goodall, 1986; Mitani, Watts & Muller, 2002). Lethal intergroup violence occurs in the context of boundary patrolling when a group of males comes upon a lone male from a neighboring community (Wrangham, 1999). Based on long-term field observation, the function of lethal intergroup aggression appears to be the elimination of neighboring males to provide improved safety, more territory, and occasionally more females (Goodall, 1986; Wrangham, 1999). Indeed chimpanzee males are heavily reliant on alliances with other males, and have complex social behaviors that facilitate within-group solidarity (de Waal, 2000; Melis, Hare, Tomasello, 2006). At the same time, males compete within their groups to form dominance hierarchies that result in priority access to estrous females (Goodall, 1986).

The chimpanzee pattern of intrasexual competition stemming from male philopatry is somewhat unique among primates, but is shared with humans, as revealed by population genetic research, among other lines of research (e.g., tribal warfare; Keeley, 1996). Y-chromosomes are passed only among males, whereas mtDNA is passed exclusively by females. Variability in the distribution of Y-chromosome and mtDNA polymorphisms provides clues about the philopatry of mating system. Seielstad, Minch and Cavalli-Sforza (1998) found that Y-chromosome variants for humans tend to be more geographically localized than mtDNA sequences, suggesting male philopatry. These patterns are in accord with ethnographers that suggest around 70% of extant cultures are patrilocal (Burton, Moore, Whiting & Romney, 1996).

Chimpanzees also share a similar life history with humans. Maturation is prolonged, in theory to accrue and develop complex social competences that covary with later reproductive prospects (Bogin, 1999; Kaplin, 1996; Bock, 2004). Juvenile chimpanzee males begin to affiliate with adult males from an early age, learning social skills in the context of cooperative competition. For adult males, survival and reproduction depends on having coalitional support, the expression of within-group aggression is intricately constrained and followed up by reconciliatory behaviors (de Waal, 2000). Reconciliation is complex package of skills in primates that is developmentally labile (de Waal & Johanowicz, 1993).

Evolution and Development of Boys' Social Behavior

Geary et al. (2003) proposed that sex differences in behavioral and motivational dispositions in humans can be traced to a modal social ecology that centered on male-philopatry and coalitional group-on-group competition, and within-group dominance hierarchies, as I described above. In this context, humans are predicted to have evolved motivational and behavioral biases that encourage cooperative within-group and competitive between-group interactions (Geary, 1999). In line with this prediction, humans have been shown to exhibit strong intergroup biases (Asch, 1952; Sheriff, 1966). Similarly, Arnt, Greenberg, Solomon, Pyszczynski, and Simon, (1997) showed that when ones' mortality is primed humans support ingroup ideologies much more readily, consistent with the predicted relation between within-group solidarity and competitiveness vis-à-vis out groups.

By placing sexual selection within the context of a species life history, we can understand the proximate functions of developmental patterns that result in a species-typical phenotype and sex differences therein. As mentioned above, it has been hypothesized that the function of the human childhood is to allow the accrual of learned competencies that improve reproductive potential (Bogin, 1999; Kaplin, 1996; Bock, 2004). Geary et al. (2003) argued that to practice and refine reproductive competencies, the child would have to be biased to recreate the social dynamics that defined successful species-typical intrasexual competition. These dynamics are illuminated by those aspects of the social environment that were uniquely human:

> "No other sexual organisms compete in groups as extensively, fluidly, and complexly as humans do. No other organism at all, plays competitively group-against-group. Most importantly, so far as we know, in no other species do social groups have as their main jeopardy other social groups of the same species…"(Alexander, 1987, p. 80).

Sex differences in social development indicate that from an early age boys and girls self-segregate and create isolated sex-specific social environments (Maccoby & Jacklin, 1987; Maccoby, 1998). In a recent meta-analysis, Rose and Rudolph (2006) found that boys engage in more rough-and-tumble competitive play, form larger playgroups and engage in group-level play more frequently than girls. Moreover they found that boys groups are characterized by well defined in-group dominance hierarchies, facilitating, in theory, the social cooperation that will enhance their success in intergroup competition. In accord, Lever (1978) found that boys engage in more complex play characterized by role-differentiation, greater group-size, player interdependence, and rules. Savin-Williams (1979) proposed that in adolescent males the dominance hierarchy facilitates group-level competition by reducing within-group conflict, and supporting division of labor through role differentiation.

Parsing the social from biological influences on sexually dimorphic human behavior is difficult, but there is evidence that the prenatal testosterone exposure has effects outside of socialization (for review Cohen-Bendahan, Beek & Berenbaum, 2004). Congenital adrenal hyperplasia (CAH) is a genetic disorder that results in exposing a fetus to relatively high levels of adrenal androgens (i.e., the class of steroids to which testosterone belongs; White & Speiser, 2000). Though affected girls can be born with virilized genitalia, they are typically surgically altered at birth and parents report that they do not treat their affected daughters differently than unaffected daughters, which suggests that social influences may be minimal (Berenbaum, 1999). Relative to unaffected sisters, girls with CAH are behaviorally masculinized and defeminized, despite postnatal hormonal treatment. More specifically, girls with CAH show increased play with male-typical toys and less play with girls toys (Berenbaum & Hines, 1992), a small preference for male playmates (Berenbaum and Snyder, 1995), engage in more rough-and-tumble play (Hines & Kaufman, 1994), report higher levels of aggression (Berenbaum & Resnick, 1997), perform better on some spatial tasks (Resnick, Berenbaum, Gottesman, & Bouchard, 1986), and exhibit long-term identification as a tomboy by themselves and others (Ehrhardt & Mayer-Bahlburg, 1981).

Geary et al. (2003) put forth an evolutionary model suggesting that boys may have evolved biases that facilitate the formation of cohesive in-groups that in turn enhance group-level competitive competencies, which are practiced during childhood; Rose and Rudolph support their assertion. Further, these biases appear to be related to prenatal testosterone exposure, at least in part.

Proximate Mechanisms: Testosterone and Cortisol

Testosterone and Animal Models

Androgens are a class of anabolic steroid, the function of which is to stimulate protein synthesis and muscle growth, the growth of bones, and production of red blood cells (Fox, 2004). Testosterone is the primary mammalian androgen and produced primarily but the testes, but also in small quantities from the adrenal glands of both males and females (Carlson, 2004).

Testosterone interacting with chromosomal sex can account for most of the known sex differences in neural structure among non-human vertebrates (Morris, Jordan & Breedlove, 2004; Arnold, Xu, Grisham, Chen, Kin & Itoh, 2004). Gonadal hormones, principally testosterone, first organize prenatal central nervous tissue destine to mediate sex typical behaviors, and later in life activate those tissues transiently, contingent upon circulating hormones (Mann and Fraser 1996; MacLusky & Naftolin, 1981; Feder, 1984).

One activational effect is an increase in male-on-male aggression in response to challenge. In general, testosterone facilitates intrasexual aggression in animals when they are reproductively active (Archer, 1998). For example, male-on-male reproduction-related aggression tracks life history changes in testosterone in mice. Both testosterone and aggression increase at puberty and are reduced with castration; and replacement following castration reinstates behavioral aggression (Schechter & Gandelman, 1980).

Life history and situational variation in testosterone levels reflects an evolved trade-off between survivability and reproduction (Meuhlenbein & Bribescas, 2005). To avoid immunosuppressive effects of testosterone (Folstad & Karter, 1992) and competition related injuries, Wingfield, Hegner, Dufty, and Ball (1990) proposed the Challenge Hypothesis to account for such life history trade-offs. Wingfield's hypothesis predicts testosterone levels rise moderately at the beginning of the breeding season to facilitate activation of the competitive, physiological, and behavioral changes need to compete for territory and mates. During challenges relevant to reproduction, testosterone levels rise further. These increases result in the expression of male-male mate competition: territory formation, fight for dominance, and guarding mates.

Muller and Wrangham (2004) showed, in general, that the challenge hypothesis may also apply to chimpanzees. Unlike seasonally breeding animals, chimpanzees maintain sufficient testosterone levels to reproduce year round. However, testosterone increases in response to individual challenge. Muller and Wrangham found that for males testosterone rises in the presence of sexually receptive females, and primes males to compete for mating access. However the relation between testosterone and aggression was only evident for higher ranking males, the ones that could possibly win a dominance contest. It is important to note that high ranking males are not necessarily the ones that are the most physically dominant, but the ones with enough social skills to garner support from other males during conflicts.

Testosterone and Humans

For normally developing boys, testosterone levels increase at puberty and are involved in the development and maintenance of secondary sexual characteristics, including growth of facial and pubic hair, muscles, growth of larynx, and sex drive. After childhood, testosterone shows diurnal fluctuations, being highest in the morning and declining thereafter (Dabbs, 1990). Controlling for diurnal variation, individual differences in testosterone levels are highly consistent within adults, even over the course of many years (Granger, Shirtcliff, Booth, Kivlighan & Schwartz, 2004).

Post-puberty, testosterone exerts transient activational effects by interacting with the prenatally organized androgen receptors throughout the body. The activational effects on human behavior is not thought to be a cause-and-effect mechanism, but rather interact with individual differences in experiences and perceptions, and can influence proclivities for certain behaviors within the particular social context (Booth el al., 2006). For example, testosterone appears to influence sexual interest. Bagatell et al. (1994) showed that in normal men, the experimental manipulation of testosterone levels resulted in a significant increase in sexual thoughts. In a related study, sexual interest, frequency of erections, and orgasmic frequency varied with endogenous androgen levels (Knussman, Christianson, & Couwenbergs, 1986). Hellhammer, Hubert, and Schurmeyer (1985) found that men who watched erotic movies compared to sexually neutral movies exhibited increased testosterone secretion, suggesting that the context can affect testosterone levels, as it does in other species.

The relation between testosterone and sexuality remains parallel across the life course with testosterone levels mirroring average sexual activity, that is, it is near its peak in early adulthood and declines thereafter (Christianson, 2001). Similarly, life history patterns of testosterone closely follow the demographic patterns of aggression in humans. In a meta-analytic review, Archer (2004) found that at all ages boys and men were more physically aggressive than girls and woman. The pattern held across cultures, occurred after childhood, peaked in early adulthood, and declining thereafter. Homicide and violence most commonly occur between men in their late teens to early adulthood, as typically related to dominance issues and sexual jealousy (Wilson & Daly, 1998).

However, the human literature is highly inconsistent as to whether testosterone has a direct activational effect on aggression, as it appears to in other animals. In general, meta-analyses suggest only weak and inconsistent associations between testosterone levels and aggression in adults. Ultimately, the association between circulating testosterone and aggression is moderated by variables such as individual differences in experience and personality, as well as social context (Archer, Birring & Wu, 1998; Book, Starzyk & Quinsey, 2001; Archer, Graham-Kevan & Davies, 2005).

Some of the moderating variables are associated with what Archer (2006) describes as a shorter-term mating strategy, that is, a strategy that emphasizes mating at the expense of parenting. His meta-analytic review shows that testosterone levels are associated with a more extraverted, impulsive, uninhibited, and dominant personality.

Moreover, testosterone is inversely related to parental effort (Grey, Yang & Pope, 2006) and positive spousal relations, but is positively related to having multiple sexual partners (Anders, Hamilton & Watson, 2007)

Wilson, Daly, and Pound (2002) propose that testosterone in human males may serve as an assay of mating effort (i.e., as opposed to parenting effort), rather than directly with aggression. In particular the relation between age and homicide rates parallels the above mentioned life history patterns of mating effort. In their view, testosterone modulates competitive risk taking, differentially depending on context. For example, in response to challenge, lethal aggression occurs most commonly the context of social inequity, being manifested as future discounting and impulsivity. Conversely, testosterone in the context of professional challenge could be manifested as motivation to succeed. In their respective contexts, both are manifestations of motivation to achieve dominance and therefore enhance access to social and material resources.

Stress

A prototypical stressor in nature (e.g., attack by a predator) calls for vigorous activity. The autonomic and endocrine responses are therefore catabolic, or function to free and mobilize energy (Carlson, 2004). The first wave of the prototypical stress response following an external trigger involves enhanced secretion of catacolamines (i.e., epinephrine and norepinephrine) from the sympathetic nervous system, and over the course of minutes the secretion of glucocorticoids, which in primates is cortisol. The release of glucocorticoids results in the inhibition of gonadal steroid secretion, including testosterone, the diversion of energy and blood to exercising muscle via enhanced cardiovascular tone, inhibition of energy storage, inhibition of reproductive physiology, decreased appetite, and a sharpening of cognition and attention (Sapolsky, Romero, Munck, 2002). In general, the stress response occurs in the context to both physical and psychological stressors for humans (Sapolsky, 2005; Dickerson & Kemeny, 2004)

The function of mounting a stress response is coping with challenges to homeostasis. In the context of competition, coping is done through modulation of not only physical, but mental faculties. McEwen and Sapolsky (1995) suggest the effect of glucocorticoids on memory fits an inverted U-shaped dose response curve so that at either extreme memory is impaired, whereas at moderate levels glucocorticoids enhance memory formation, by sharpening memory consolidation and retrieval; more recent empirical studies support this hypothesis (Abercrombie, Kalin, Thurow, Rosenkranz & Davidson, 2003; Abercrombie, Speck & Monticelli, 2006). Glucocorticoids appear to function adaptively by enhancing memory of previous successful coping attempts and through this the avoidance of future homeostatic disturbances by the same stressor (Sapolsky et al., 2002).

Biosocial Model and Competitive Coping

The original theory of male testosterone response to challenge in humans is the biosocial status model (Mazur, 1985). In keeping with research on other primates, the proposal is that humans allocate status rank through face-to-face interaction. With impending competition, individuals are predicted to respond through increases in testosterone, which in turn increases the individuals' assertiveness in seeking or maintaining status, as well as their ability to physically respond to the challenge. The outcome of the competition is predicted to affect post-competition behavior and physiology. Specifically, the winners' levels increase, encouraging further challenges and status seeking, and the losers' levels decrease, encouraging withdrawal from further competition.

Some studies support an outcome based testosterone increase for winners and decreases for losers (Gladue, Boechler, & McCaul, 1989; Mazur & Lamb, 1980; McCaul, Gladue, & Joppa, 1992). However, the results are mixed across the entire literature (Gonzales-Bono, Salvador, Serrano, & Richarte, 1999; Mazur, Susman & Edelbrock, 1997; Schultheiss, Campbell, & McClelland, 1999; Suay & Salvador, 1999; Salvador, Simon, Suay, & Llorens, 1987). The lack of consistency suggests that factors other than outcome influence hormonal response to competition. For example, Serrano, Salvador, Gonzalez-Bono, Sanchis, and Suay (2000) found in a judo competition that testosterone levels were only positively associated with self appraisal of performance and attributions of outcome to personal effort. Also, cortisol showed significant relationship with negative mood. All in all, suggesting emotional and cognitive mediators of the hormone response to competition.

Salvador (2005) proposed that individual differences in the ability to cope with a competitive situation, mediates the relation between outcome and testosterone levels. Herein, the implicit assumption is that biosocial model reflects an optimal response to competition, and deviations reflect individual differences in the ability and availability of resources to cope with the competitive situation. Positive mood (Booth, Shelley, Mazur, Tharp & Kittok, 1989; McCaul et al., 1992), attributions (Gonzalez-Bono et al., 1999; Gonzalez-Bono, Salvador, Ricarte, Serrano & Arnedo, 2000), expectations (Suay, Salvador, Gonzalez-Bono, Sanchis & Martinez, 2000), appraisal (Serrano et al., 2000) and anxiety (Passelergue & Lac, 1999) have been proposed to influence and predict hormonal response to winning. Moreover, an individuals life outside of the competition may or not be conducive to optimal coping, such as the nature and quality of peer and family relations, or the individual's assessment of their efficaciousness and social skills (Booth, Granger, Mazur & Kivlighan, 2006). These aspects of the individual may set the stage for basal hormones and reactivity to real world events and therefore, necessarily to the experimental event.

Schulthesis, Campbell, and McClelland, (1999) similarly questioned the efficacy of a reflexive increase in testosterone levels following a contest win, proposing that individual differences in motivational factors would mediate the relation. They incorporated an implicit measure of power motivation. Implicit power motivation is described as the recurrent concern to influence others, is assessed by analyzing individual's responses to picture cues, and is not correlated with written measures. In dominance contests, individuals high in implicit power motivation show increases in cortisol after losing, but individuals with lower power motivation show cortisol increases to winning, suggesting that winning for one with low power motivation is stressful and that losing for one with high power motivation is stressful (Wirth et al., 2006).

Schultheiss and Rohde (2002) showed that in power motivated winners of a laboratory contest, testosterone levels after the competition correlated with implicit learning during the task; this relation was statistically mediated by testosterone increases. Similarly, Schultheiss et al. (1999) described two types of implicit power motivation, one in which the individual is motivated for personalized power, attained through assertion. The other, socialized power, attained through prosocial behaviors. In a laboratory experiment, they showed that the win-related increased testosterone levels was found for men with a high personalized power motive and low socialized power motive.

All in all, in appears that an outcome only model for hormone response to competition is not adequate; the literature suggests that the individual's perceptions and interpretation together with his personal and situational traits must be taken into account.

Testosterone Cortisol and Competition

To study a competitive event, researchers often parse the event into a pre-vent, event, and post-event phases. Testosterone and cortisol increases are expected across the pre-event phase in preparation for challenge (Wingfield, 1990; Mazur, 1985). Pre-event increases in testosterone levels are proposed to increase risky strategies (Daltzman & Zuckerman, 1980), improve cognitive performance (Klaiber, Broverman, Vogel, Abraham & Cone, 1971), improve psychomotor function and coordination (Herrman & Beach, 1976).

Pre-event testosterone has been suggested to be related to focus on upcoming competition, and individual competitiveness (Mazur & Booth, 1998). Kivilghan et al. (2005) found that pre-event testosterone was associated with interest in social affiliation and bonding with teammates, but high levels of pre-event testosterone predicted poor performance in an ergometer rowing competition.

Pre-event cortisol is related to pre-event mental preparation. Pre-event increases in testosterone may not occur if the individual does not perceive the competition as important (Mazur, Booth & Dabbs, 1992; Salvador et al., 1987; Booth et al., 1989), or that the opponent has a very different skill level (Mazur & Lamb, 1980).

Depending on the outcome, testosterone is predicted to increase for winners and decrease for losers (Mazur, 1985). High testosterone post-event has been shown to relate to positive mood and elation (Booth et al., 1989; Mazur & Lamb, 1980). Winners, however, do not always exhibit higher testosterone. For example, external attributions of winning negatively correlate with testosterone for winners, but positively for losers (Gonzalez-Bono et al., 1999). If the winner attributes success to luck (McCaul et al., 1992), or if they do not take the match seriously (Mazur et al., 1997; Salvador et al., 1987), they may not show an increase in testosterone.

Testosterone Cortisol and Group Competition

The dynamics of testosterone and cortisol in coalitional competition, to the best of my knowledge, have not been fully assessed; however, several studies are potentially relevant. Salvador, Simon, Suay, and Llorens (1987) assessed testosterone and cortisol in Judo competition in which they paired each member of a regional team with random non-members. The result was that members of the team were not fighting each other, only non-members who were not part of any team. Only the regional team showed increases in testosterone after the fight, whereas non-members showed a decrease. Cortisol showed the opposite pattern with team-members showing lower cortisol and non-members showing increases. The authors proposed that rank, experience, and status were important in predicting competitive response. However, in addition it may be that being a member of the team protected the individual from stress-related increases in cortisol, allowing competitive coping, as testosterone was higher and cortisol was lower for team-members, as opposed to non-team members.

Mazur et al. (1992) examined men's testosterone in response to chess matches. The sample was composed of members from a chess club that met once a week year round. Individuals were assigned to matches based on skill. Due to methodological circumstances, it is difficult to draw firm conclusions from this study (as discussed in Archer, 2006), but the testosterone patterns for the first part of the study were generally inconsistent with predictions of the biosocial model. For the first part of the study, members of the team were paired off to compete for a position at a regional tournament. Testosterone was measured the day before, the morning of and after the competition. Mazur et al. found that all of the losers had high testosterone the day before the competition and these levels declined across the competition period, whereas winners increased the morning before and showed similar declines across the competition period. The authors concluded that for the first part of the study, the players did not take the matches very seriously.

The second part of this study followed the chess club winners to a series of regional championship rounds, essentially between-group matches. However, in this condition testosterone was not measured at regular intervals. The results that were interpretable (i.e., timing of measurement does not include pre-event, event, and post-event) supported the biosocial model. In particular, that testosterone was higher for winners. From an evolutionary perspective, the key difference across the two parts of the study may have been competition within the in-group versus competition against a member of the out-group, that is, an individual from another chess club.

In a similar study, Kivlighan et al. (2005) assessed testosterone and cortisol along with measures of previous experience, dominance, competitiveness, bonding with teammates, pre- and post-competition mental state and performance in response to an ergometer rowing competition. Similar to the Mazur et al. (1992) study, a local team was paired to compete for a position at a regional competition. Consistent with Mazur et al.'s chess study, all men showed a reduction in testosterone, relative to baseline levels, before the competition and these levels declined across the competition period. Moreover, as with the chess study, higher pre-event testosterone was associated with poorer performance. Novel results came from a questionnaire that assessed competitiveness and social interests. For example, they found that men with higher basal testosterone showed reduced interest in bonding with teammates, and that rising testosterone level across baselines to competition was positively related with interest in social bonding. Pre-event cortisol rose on average and showed an experience effect such that less experienced competitors had higher cortisol. For men, higher pre-event cortisol was related with increased competitiveness, and mental preparation. In following up at the regional competition, results supported the biosocial model. In particular, there was not the same pre-event drop in testosterone, but rather increases in testosterone for winners.

A final study of interest assessed testosterone and cortisol contrasting in-group versus out-group competition using a Dominos competition (Wagner et al., 2002). Participants were men from a rural Dominican village that were paired to compete in within-village and between-village matches. Drawing conclusions from this study is difficult due to difficulties in conducting a field study. For example, individuals can exhibit testosterone and cortisol changes similar to competition vicariously, through observation of sporting events (Berhardt, Dabbs, Fielden, & Lutter, 1998). Holding dominos matches in succession, allowed village-mates to witness each others wins, which could affect their pre-event testosterone and cortisol levels. There was an argument during the within-village match which appeared to affect at least one participant. For the between-village matches, the men had to travel to the neighboring village the morning of the matches, resulting in variance in cortisol due to physical exertion. The sample was small (*n*=8) of which only 4 participated in the between-village matches.

Nonetheless, the results are of interest. Overall, cortisol levels significantly increased before the matches and more so before the between-village matches. Testosterone levels did not show significant changes across the matches and there were not clear winner or loser effects. For the within-village matches, testosterone levels decreased immediately pre-match and immediately post-match for all four losers, as well as in all four winners. Of those whose testosterone dropped across the competition period, two of the four losers and none of the three winners exhibited a rebounded to baseline. The differences within versus between were that all four men that participated in both exhibited higher testosterone immediately after the within-village match.

An important caveat is that both the Kivlighan et al. (2005) and Mazur et al. (1992) competitions took place early in the day. Testosterone and cortisol both show diurnal fluctuations being highest in the mornings (Booth, 1995). Kivlighan et al., (2005) suggested that the early time may have imposed a ceiling effect on testosterone and cortisol, which in turn could have masked changes in response to competition.

Proposed study: Hormonal Response in Coalitional Male-Male Competition

I used a videogame to provide simulated competition in a controlled laboratory environment free of extraneous testosterone- and cortisol-eliciting stimuli. A videogame is ideal for this type of study, because it is easily replicable and allows for control of the competitive (virtual) environment, which remains constant between conditions. It is appropriate to point out that videogames have been used by Mazur et al. (1997) and though their study did not find the predicted patterns–testosterone did not increase for winners–I agree with their conclusions. That is, that the game (i.e., Pong®) may not have stimulated competition in the participants.

I did not predict a homogenous testosterone and cortisol response to competition. Individual differences in traits, context and perception were expected to influence the hormone outcome response. To assess traits of the participant, I used IQ, personality, state anxiety levels, and a questionnaire measure to assess social and leadership skills. To control for timed correlates, concurrent with hormone assessment I assessed state anxiety, mood, expectations/attributions, and seriousness, in addition to questionnaire measures to assess perceived team hierarchical structure. Hormones were measured thirty minutes before, immediately before, immediately after, and thirty minutes after each match.

On the basis of the evolutionary model outlined above, I predicted differences in competitive motivation between the experimental conditions. In particular, in the context of group-on-group competition, males should exhibit patterns that reflect an increased motivation to compete, which should be related to increased pre-match testosterone levels. Competing within ones own group should elicit higher cortisol, reflecting the stress associated with competing against necessary allies and lower testosterone, reflecting some amount of reservation. I predicted a win effect for testosterone only for the between-group match winners, not for the within-group winners.

I also predicted that testosterone levels would be related to positive mood state, reduced anxiety, and positive expectations before and internal attributions after the tournament, across conditions. Traits, such as personality, intelligence, or aspects measured in the questionnaire, may be predictive of hormonal reactivity.

METHOD

Participants

The study included 14 three-member teams of undergraduates men (*n* = 42), with a mean age of 19 years (*SD* = .97). Participants were recruited from the from the undergraduate psychology pool at the University of Missouri and given 10 credits to participate in three practice sessions and two tournaments. Participants were paid $45 for placing first in a tournament and $15 for second, or third in the case of the within-group tournament; if a team won a between group tournament, all members of the team were paid $45 and the members of the opposing team $15. The payments were included in the study design to make the outcome of the tournaments salient and meaningful. Informed consent and debriefing forms are provided in appendix 1 and 2.

Videogame

The videogame was *Unreal Tournament 2004*® by Atari games, because it provides highly detailed graphics and two appropriate game types. For the within-team tournaments, the game type *Death Match* was used. The match provides two opposing individuals with an arena and weapons, and is scored on the bases of the number of frags (i.e., kills of the opponent) they obtain within the allotted time. Skill in this game-type requires a player to use different weapons effectively to inflict maximal damage and avoid losing points by killing themselves (some weapons kill everyone in a specific area of effect). The same arena was used for all practice sessions and the tournaments.

Coalitional between-group tournaments used the game type *Onslaught* to induce a team based strategy. In this game type, the goal for each team is to destroy the opposing team's power core, which is situated within the team's home base. Players have access to a map that contains the two home bases and a series of power nodes (like circuits) that must be captured before the team has access to the opposing team's power core. A team must capture a power node and defend it while it is being constructed. Once constructed, the captured node remains vulnerable until the next node in the series is captured and then it becomes locked. Locked nodes can not be taken; a team must take them serially. Points in this game type are allotted for destroying and constructing power nodes. Skill in the game-type requires teamwork. Players must work together, synchronize actions (e.g., take defensive and offensive positions), and be skillful with the weapons and vehicles provided.

The game is network based. Each participant's computer connected to a central local server which ran the arena and recorded the match's progress. I imposed a 30 minute time limit for both game types during tournament play.

Biological Measurements

A total of eleven saliva samples were provided by each participant. Three were provided on non-competition, practice days and averaged to serve as a baseline reference of individual variation in daily testosterone and cortisol. A total of eight competition samples where obtained, four for the within-group tournament and four for the between-group tournament.

The procedure for saliva collection requires passive drool without exogenous stimulation (e.g., gum chewing). Participants were provided a vial and a straw cut to 7.5

cm. They were asked to imagine they were eating their favorite food, or the taste of freshly cut lemon, and to allow saliva to pool in their mouths, which they then allowed to flow into a pre-labeled vial. The vial was stored on ice immediately after collection and then placed in a -20 degrees C freeze until time of assay.

Testosterone.

These samples were assayed using Enzymatic Immunoassay (EIA) (Salimetrics, Inc.), following standard procedures outlined by Salimetrics, State College, PA. The procedure is designed to capture the full range of salivary testosterone (.61 to 600 pg/mL).

Each EIA kit includes a microtitre plate coated with rabbit antibodies to testosterone. Testosterone in standards levels (supplied by Salimetrics and diluted to provide gradient against which to measure) and unknown levels (study samples) compete with testosterone linked to horseradish peroxidase (the enzyme conjugate) for the antibody binding sites. Twenty-five mL of the standards, controls, and unknowns are pipetted into appropriate wells on the microtitre plate. Next, 25 mL of assay diluent were pippetted into two wells to serve as the zero for comparison purposes and into each of the other wells. A dilution (1:1000) of the enzyme conjugate was made by adding 18 µL of the conjugate to the 18 mL of assay diluent. 150 µL of this solution was immediately pippetted into each well using a multichannel pipette. The plate was then mixed on a rotator for 5 minutes at 500 rpm and incubated at room temperature for 55 minutes.

After incubating, unbound components were washed out 4 times with a wash buffer. Next, 300 µL of the substrate tetramethylbenzidine (TMB) was added to each well with a multichannel pipette. The solution was mixed on a plate rotator for 5 minutes at

500 rpm and the plate placed in the dark at room temperature for an additional 25 minutes. Finally, 50 µL of stop solution was added to each well via a multichannel pipette to stop the enzymatic reaction. This was mixed on a plate rotator for 3 minutes. The plate was placed on a plate reader within 10 minutes of adding the stop solution. Bound testosterone peroxidase was then measured by the reaction of the peroxidase enzyme on the substrate tetramethylbenzidine, which produces color differences. These differences in optical density were read on a standard plate reader.

All samples from an individual were assayed in duplicate in the same assay batch. Since all samples were assayed in duplicate, the mean intracoefficient of variation provides a measure of the average variability for each assay from the same sample. The mean intracoefficient of variation was 7.78%. The mean intercoefficient of variation provides a measure of the average variation from the controls provided in the assay kits. In other words, it is the average difference from expected values for the control samples. Mean intercoefficient of variation for this study was 14.24%.

Cortisol.

These samples were assayed using Enzymatic Immunoassay (EIA) (Salimetrics, Inc.), following standard procedures outlined by Salimetrics, State College, PA. The procedure is designed to capture the full range of salivary cortisol (0.003 to 3.00 ug/dL).

Each EIA kit includes a microtitre plate coated with monoclonal antibodies to cortisol. Standard cortisol levels (supplied by Salimetrics) and unknown cortisol levels (study samples) compete with cortisol linked to horseradish peroxidase (the enzyme conjugate) for the antibody binding sites. Twenty-five mL of the standards, controls, and unknowns are pipetted into appropriate wells on the microtitre plate. Next, 25 mL of assay diluent were pippetted into two wells to serve as the zero for comparison purposes and into each of the other wells. A dilution (1:1600) of the enzyme conjugate was made by adding 15 µL of the conjugate to the 24 mL of assay diluent. Two hundred µL of this solution was immediately pippetted into each well using a multichannel pipette. The plate was then mixed on a rotator for 5 minutes at 500 rpm and incubated at room temperature for 55 minutes.

After incubating, unbound components were washed out 4 times with a wash buffer. Next, 200 µL of the substrate tetramethylbenzidine (TMB) was added to each well with a multichannel pipette. The solution was mixed on a plate rotator for 5 minutes at 500 rpm and the plate placed in the dark at room temperature for an additional 25 minutes. Finally, 50 µL of stop solution was added to each well via a multichannel pipette to stop the enzymatic reaction. This was mixed on a plate rotator for 3 minutes. The plate was placed on a plate reader within 10 minutes of adding the stop solution. Bound cortisol peroxidase was then measured by the reaction of the peroxidase enzyme on the substrate tetramethylbenzidine, which produces color differences. These differences in optical density were read on a standard plate reader.

All samples from an individual were assayed in duplicate in the same assay batch. Since all samples were assayed in duplicate, the mean intracoefficient of variation provides a measure of the average variability for each assay from the same sample. The mean intracoefficient of variation was 6.66%. The mean intercoefficient of variation provides a measure of the average variation from the controls provided in the assay kits. In other words, it is the average difference from expected values for the control samples. Mean intercoefficient of variation for this study was 13.59%.

Psychometric Questionnaires

Preliminary Screening.

The first section of the preliminary questionnaire included items on demographic and contact information for the participant. The second section had two purposes. The first was to provide information useful in understanding individual traits, in particular traits that could predict the optimal coping response, such as the individuals social and peer context outside of the study that my interact with the competition or buffer the individual from stressors (i.e., Granger et al., 2006; Gunnar & Donzella, 2002); for example, self-perceived social support, and whether people generally like them. The second purpose was to assess traits that predict leadership ability in the context of coalitional competition, such as social skills and a preference for status; for example, self-report of dominance, sociability, leadership, respect by others. (See Appendix 3).

Other questions included whether they were in stable relationship, because being in a relationship status is related to lower testosterone levels (Burnham, et al., 2003), and experience (as described in Salvador, 2005) with Unreal Tournament, PC gaming in general, and team experience.

Intelligence.

To assess if intelligence is related to tournament skill, leadership, or changes in these across sessions, the *Standard Progressive Matrices* was administered (Raven, Court & Raven, 1993). The test was started with the item representing IQ of 80 for adults (which should be well below the functioning of this sample of college students), and participants were given credit for all items up to this level. In total there were 60 items, 36 of which were credited to the participant due to their expected ease. Correct responses on the remaining 24 items were summed and added to 36. The mean response of the sample was 55.32 (SD=2.76).

Personality.

The bipolar measure of the Big 5 dimension of personality was administered (Goldberg, 1993). These dimensions are introversion-extroversion, agreeableness, dependability, emotional stability, and openness to experience. The items are arranged with descriptors, for example "introvert-extroverted" separated by a scale from "1" to "9" with "5" being neutral. Participants are asked to rate themselves as they see themselves at the present. The big five personality inventory was made up of five factors, with 10 items each.

State-Trait Anxiety.

Anxiety was assessed using *State-Trait Anxiety Inventory* for Adults (STAI-Y-1; Spielberger C.D, 1983). Trait anxiety is described as the general tendency for individuals to experiences anxiety, or the average level of anxiety as a personality trait. The trait measure is a 4-point scale consisting of 20 items, such as "bushed", which are summed to provide a composite score. For each item, participants are asked to respond as the descriptor generally applies to them. The trait measure was administered at all three practice sessions and the average taken to provide a baseline reference for interpreting anxiety levels during each tournament. The state measure uses the same construction, but asks how the items apply in current situation, or right now.

Profile of Mood States.

Mood was assessed using the *Profile of Mood States* (POMS) Standard Form (McNair et al., 1971), which was derived for usage with non-clinical populations such as college students. POMs is composed of 65 items divided into 6 factors. Each factor consists of a number of adjectives that can be used to describe a person's feelings, and asks how well on a four-point scale those adjectives describe their current state. The factors defined by POMs are *Tension-Anxiety* (heightened musculoskeletal tension), *Depression-Dejection* (depressed mood and personal inadequacy), *Anger-Hostility* (anger and antipathy toward others), *Vigor-Activity* (high energy), *Fatigue-Inertia* (wariness), and *Confusion-Bewilderment* (cognitive inefficiency or disorganized emotion). The factors are summed and subtracted from vigor, to provide a general mood disturbance score.

Time – Questionnaires.

Each tournament was divided into four parts. At the beginning of each segment (i.e., four segments per tournament) participant was given time1, time2, time3, and time4 questionnaires, respectively. (See Appendix 4). Each questionnaire had a section in which the participant ranked himself and his teammates in order of skill level in the game.

Time1 differed in that it has two additional sections. The first, a section called confounding history, was scaled from 1 to 7 and included items on variables that could influence hormone values outside of tournament play; these were eating a major meal, consuming dairy products, consuming acidic or high sugar foods, bushing teeth, sexual activity, prescription medications, other medicinal agents and alcohol consumption (see Christiansen, 2001). The second additional section, asked the participant if they had experienced an unusually stressful event recently, the stress variable was dichotomously coded.

The time 2 questionnaire was largely the same as time 1, but omits the confounding history, and stressful event variables. However, it included two questions asking how they expect to play in the upcoming tournament, and how they expect their teammates to play.

The time 3 questionnaire asked the participant how they did play and how their team did play, and had one new section. This questionnaire included a free response section, asking how seriously they took the match and why they won or lost. The time 4 questionnaire, was the same as time three, however it omitted the free response section.

The ranking section from each questionnaire was used to create agreement scores which were coded (1-9) according to the number of agreements between the three participants of each team, in their perception of the rank order of skill within the team. Agreement scores were used a manipulation check to insure that participants were aware of rank.

Procedure

Data were collected over the course of two semesters. Initially, participants were to be paired for between group matches according to skill level. However, during the first semester (i.e., for three teams) it proved too difficult match the schedules of closely rated teams for all participants and a sham team was created. The sham team was comprised of an undergraduate research assistant that had little experience with Unreal Tournament and two of his friends with similar experience. The only other difference between the semesters was that for the first semester, practice sessions were kept completely separate so that only one team was in the computer lab at a time. In the second semester, to solve the problem of scheduling tournaments, I had both teams meet in the computer lab, separated by a wall. In this way, they had practice sessions at the same time as the team that they would eventually play in the between-group tournament, while restricting contact between them.

The first three visits to the lab were practice sessions (p1, p2 and p3); these sessions lasted two hours per each. During each practice session saliva was collected for baseline references and the STATi was given to be averaged for trait anxiety. On p1 the personality inventory was given, whereas on p2 IQ was assessed. The fourth and fifth visits were the within-group tournament or the between-group tournament. Both tournaments were conducted as similarly as possible and divided into four sections. Each section consisted of first providing saliva and then filling out the timed (e.g., t1) questionnaires. The first section started 45 min before the actual tournament (e.g, time 1); the second directly before the tournament began (e.g., time 2); the third was immediately after the tournament ended (e.g. time 3); and, the fourth section 45 min after the tournament ended (e.g., time 4).

RESULTS

Dominance Hierarchy

Means and standard deviations for agreement scores are provided in Table 1. Descriptive statistics were adjusted for actual order of tournament play per team, so that time 1 is the first tournament time played, regardless of whether the team played the within or between group tournaments first. No hypothesis tests were performed on agreement scores. However, means are plotted in Figure 1. A team score of 9 would indicate complete agreement between the three team members as to who was the best player, who was second, and who was third. As shown in the table and figure, there was strong agreement among team members about the within-group dominance hierarchy.

Hormones

Means and standard deviations for testosterone and cortisol are presented in Table 1. Missing values–3.96% and 2.82% for testosterone and cortisol, respectively–were replaced by the group means from the corresponding time of measurement. The cortisol values were positively skewed, and therefore a square root transformation was used for all subsequent data analysis, although raw values are presented.

Tournament Type

Separate 2 (between-group vs. within-group) x 4 (times within each tournament) repeated measures ANOVAs were used to test the hypothesis that testosterone and cortisol measurements would differ across tournament type and time. For testosterone, the main effects of tournament type, $F(1,38) = 2.39$, $p > .10$, and time, $F(3,114)<1$, were non-significant, as was the interaction, $F(3,114)<1$. For cortisol, the main effect of tournament type was non-significant, $F(1,38) < 1$, but there was a main effect of time $F(3,114)=12.62$, $p<.0001$; the interaction was not significant $F(3,114)=1.04$, $p<.5$. Follow up contrasts revealed that cortisol at time 1 (30 minutes before game play) was

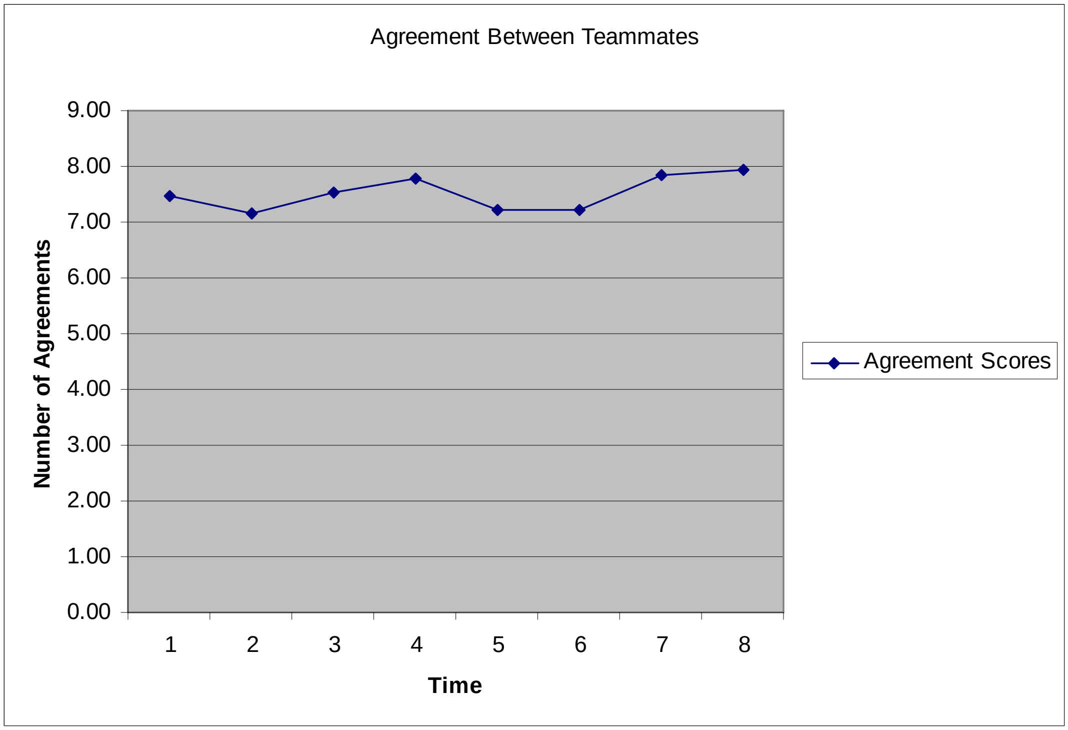
Table 1

Means and Standard Deviations for agreement scores across tournaments.

Time	*M* (n=13 teams)	SD
1	7.46	1.81
2	7.15	1.86
3	7.54	1.66
4	7.77	1.24
5	7.23	1.79
6	7.23	1.79
7	7.85	1.52
8	7.92	1.61

Figure 1

Mean agreement scores plotted by time adjusted for sequence of tournaments.



significantly higher than that at time 2 (immediately before game play), $F(1,38)=12.88$, $p<.0001$, and cortisol at time 2 was significantly higher than that at time 3 (immediately after game play), $F(1,38)=8.5$, $p<.01$.

Winner and Rank Effects

To examine whether winners or losers differed in hormone response, separate repeated measures ANOVAs were computed for each tournament type and separately for testosterone and cortisol. The outcome (win=1, lose=0) was a between subjects variable, and time was within-subjects. Based on previous findings (Booth et al., 1989), an a priori dependent *t*-test–contrasting the time 3 and time 4 measurements–was used to test the hypothesis that winners will show a post-match rise in testosterone. A winner effect might also emerge for overall rank across both teams (i.e., 1st through 6th), given players received video screen feedback on their rank, as is typical for this game, during the tournament. To test this hypothesis, the repeated measures ANOVA was redone, substituting rank for win/loss. To accommodate the later regression analyses, rank was reverse coded such that 1st place was coded 6, 2nd place 5 and so forth.

Table 2.

Descriptive Statistics for Testosterone and Cortisol

	Testosterone (pg/mL)				Cortisol (ug/dL)			
Session Type	Time	N	*M*	SD	Time	N	*M*	SD
Practice	1	37	86.03	50.17	1	38	0.14	0.11
	2	38	83.35	38.77	2	39	0.20	0.18
	3	38	83.00	48.76	3	38	0.13	0.08
Between	1	36	82.20	44.99	1	36	0.14	0.11
	2	38	84.18	47.61	2	38	0.10	0.09
	3	35	90.75	56.70	3	36	0.08	0.09
	4	37	80.25	48.52	4	37	0.09	0.10
Within	1	38	77.86	46.07	1	38	0.17	0.20
	2	39	77.14	49.51	2	39	0.13	0.14
	3	38	72.54	53.40	3	39	0.07	0.10
	4	38	74.48	47.23	4	39	0.08	0.07

Between-Group Tournament

Outcome. For testosterone, neither the main effects of outcome, $F(1,37)=1.54$, $p<.25$, nor time $F(3,37)<1$, nor the interaction, $F(3,37)<1$, were significant. The difference between time 3 and time 4 testosterone levels did not differ across winners and losers, $t(37)=1.30$, $p<.25$.

For cortisol, there was no effect for outcome, $F(1,37)<1$, but, as expected, the same main effect of time was significant, $F(3,37)=5.71$, $p = .001$; the same contrasts (e.g., time 1 vs. time 2) were significant. Again, the interaction was not significant. $F(3,37)<1$.

Rank. For testosterone, there was no significant main effects for rank, $F(1,37)<1$, or time, $F(3,111)=1.12$, $p<.25$, nor was the interaction significant. $F(3,111)<1$. For cortisol, rank was not significant, $F(1,37)<1$, but again the main effect of time was, $F(3,111)=3.55$, $p<.05$, as were the same contrasts; the interaction was not significant $F(3,111)<1$.

Within-Group Tournament

Outcome. For testosterone, neither the main effects for outcome, $F(1,37)<1$, nor time, $F(3,37)<1$, were significant, nor was the interaction, $F=(3,37)<1$. Time 3 and time 4 testosterone did not differ across winners or losers, $t(37)=.68$, $p=.50$. For cortisol, the main effect of win, $F(1,37)<1$ was not significant, but the main effect of time was, $F(3,37)=8.31$, $p = .0001$; the interaction was not significant $F=(3,37)<1$. Follow up contrasts revealed that cortisol measured directly before the between-group competition was significantly higher (time 2, M=.31 SD=.16) than that directly after completing the competition (time 3, M=.23 SD=.14) $F(1,38)=14.72$, $p=.0005$.

Rank. For testosterone, neither the main effects of rank, $F(1,37)<1$, nor time, $F(3,111)<1$, were significant, nor was the interaction, $F(3,111)<1$. For cortisol, the main effect of rank was not significant, $F(1,37)<1$, but the a main effect of time was, $F(3,111)=9.06$, $p<.0001$, as was the interaction of time and rank $F(3,111)=3.13$, $p<.05$. The latter is further explored in the subsequent regression analyses.

Individual Differences

On the basis of previous findings, it is likely that hormonal response to competition is a product of psychological processes that interact with outcome (e.g., Salvador, 2006). For this reason, individual differences in personality, anxiety, and mood were predicted to influence a participant's testosterone and cortisol values and their hormones responses to winning or losing. I first present means and standard deviations for these measures, and then use correlations to determine which individual differences variables were consistently related to the hormone variables. I did not adjust the alpha for multiple correlations, because these were only exploratory analyses. These preliminary results were then used to guide the subsequent regression analyses.

Personality.

The descriptive information for the five composite personality dimensions is shown in Table 2. These scores were correlated with the hormone measures, yielding 110 correlations (i.e., 11 cortisol x 5 personality + 11 testosterone x 5 personality). The 5 significant correlations are consistent with chance (i.e., .045). Therefore, I concluded that personality dimensions were not consistently predictive of the hormone values and thus the personality variables were not retained for the regression analyses.

Table 3.

Descriptive Statistics for Personality Dimensions

Dimension	*M*	SD
Extraversion	6.74	1.10
Agreeableness	7.29	0.88
Conscientiousness	6.36	1.10
Emotional Stability	6.89	1.00
Intellect	7.39	0.70

Anxiety.

The mean of the trait anxiety measures was not significantly different from the means of the state anxiety measures and therefore former was not an appropriate baseline to create change scores for the latter. State anxiety was assessed at the time each saliva sample was collected and the anxiety ratings were correlated with the corresponding hormone measures. Only 2 out of the 128 correlations between the 8 State anxiety measures and the corresponding hormone values were significant. For the between-group tournament state anxiety at time 4 correlated with testosterone at time 4, $r(38)=.37$, $p<.05$. For the within-group tournament state anxiety at time 4 correlated with testosterone at time 3, $r(38)=.32$ $p<.05$. Because these two correlations were likely due to chance, the state anxiety measures were not retained for the regression analyses.

Mood.

Mood was assessed at the time each saliva sample was collected and the mood ratings were correlated with the corresponding hormone measures, and with temporally adjacent hormone measures, given the expected bidirectional relationship between hormones and mood (Mazur, 1985). For example, time 1 mood variables were correlated with time 1 and time 2 hormone values; time 2 mood variables were correlated with time 1, time 2 and time 3 hormone values.

Table 4.

Descriptive Statistics for State Anxiety

Variable	N	*M*	SD
Trait	42	36.17	6.73
Stateb1	42	35.17	9.50
Stateb2	40	37.13	10.94
Stateb3	41	34.68	7.46
Stateb4	39	32.21	8.11
Statew1	39	33.03	8.36
Statew2	39	34.03	8.86
Statew3	39	34.46	10.26
Statew4	38	32.92	9.62

Note. Stateb1 = state anxiety for the between-group tournament at time 1; w = within-group. The maximum possible score was 80.

Of the 132 possible correlations, 13 were significant with testosterone and 13 with cortisol ($p<.05$). The general pattern for testosterone, though not always significant, was negative correlations with tension, anger, confusion, fatigue, vigor, and total mood disturbance. Of the 13 significant correlations with testosterone values, 12 occurred for the between-group tournament. Nine of these were with time 1 testosterone, and all were negative. At time 1, higher testosterone levels were associated with lower reported tension at time 1 $r(39)=-.48$, $p<.001$, and at time 2 $r(39)=-.38$, $p<.05$; lower reported anger at time 1 $r(39)=-.37$, $p<.05$, and at time 2, $r(39)=-.42$, $p<.05$; lower confusion at time 1, $r(39)=-.35$, $p<.05$; lower mood disturbance at time 1, $r(39)=-.35$, $p<.05$, and at time 2, $r(39)=-.33$, $p<.05$; and lower fatigue at time 1, $r(39)=-.34$, $p<.05$, and at time 2. $r(39)=-.34$, $p<.05$.

Of the remaining 4 correlations for the between-group tournament, higher testosterone at time 2 was correlated with lower vigor at time 3, $r(39)=-.35$, $p.05$, and lower anger at time 3, $r(39)=-.31$, $p<.05$. Finally, higher testosterone at time 4 was correlated with lower vigor at time 3, $r(39)=-.44$, $p<.001$. The only significant correlation for the within-group tournament was positive correlation between testosterone at time 1 and depression at time 1, $r(39)=.32$, $p<.05$.

Cortisol showed a trend of positive correlations with total mood disturbance, confusion, fatigue, anger, depression, and tension, although these correlations were not always significant. In contrast with the findings for testosterone, all of the significant correlations for cortisol occurred during the within-group tournament. Of these 10 correlations, 7 were with time 1 cortisol. At time 1, higher cortisol levels were associated with greater reported mood disturbance at time 1, $r(39)=.41$, $p<.001$ and at time 2 $r(39)=.39$, $p<.05$; greater confusion at time 1 $r(39)=.38$, $p<.05$; greater fatigue at time 1 $r(39)=.37$, $p<.05$; greater anger at time 1 $r(39)=.33$, $p<.05$ and at time 2 $r(39)=.33$, $p<.05$; and greater depression at time 2 $r(39)=.33$, $p<.05$. Of the remaining 6 correlations, 4 were with cortisol at time 3. Higher cortisol at time 3 was associated with greater tension at time 3 $r(39)=.35$, $p<.05$, and time 4 $r(39)=.36$, $p<.05$; greater fatigue at time 3 $r(39)=.32$, $p<.05$; and greater mood disturbance at time 4 $r(39)=.35$, $p<.05$. The remaining significant correlations were with cortisol at time 4; higher cortisol was associated with greater tension at time 4 $r(39)=.40$, $p<.05$ and greater fatigue at time 1 $r(39)=.32$, $p<.05$.

Based on the pattern of these correlations, I chose to include mood disturbance and vigor in the regression analyses. Mood disturbance is particularly important because, in addition to the correlations with testosterone and cortisol, it is a composite of the other mood variables, except vigor, so that it captures much the variance due to the individual variables. For example, at time 1 for the between-group tournament, 9 of the 13 significant correlations with testosterone occurred for variables that contribute to the mood disturbance composite. The time 1 mood disturbance composite was correlated with confusion $r(39) = .77$, tension 1 $r(39)=.77$, $p<.0001$, tension 2 $r(39)=.46$, $p<.001$, $p<.0001$, fatigue 1 $r(39)=.69$, fatigue 2 $r(39)=.85$, $p<.0001$, anger 1 $r(39)=.73$, $p<.0001$, anger 2 $r(39)=.72$, $p<.0001$, $p<.0001$, and vigor $r(39)=.12$, $p<.25$.

Questionnaire.

Descriptive statistics are provided in Table 5. Of the questionnaire variables, self-perceived social competence, sociality, leadership, respect by others, and social support were highly correlated; see Table 6. On the basis of these correlations, I created a composite variable, Leader; alpha = .94. The Leader variable was significantly correlated with the theoretically important testosterone at time 4 for the between-group tournament, $r(39)=.33$, $p<.05$, and thus retained for the subsequent regression analyses.

Attributions, Seriousness, and Cooperation

For the free response questions posed at time 2 and time 3, three variables were coded; internal versus external attributions, how seriously the participants took the match, and between-group tournament cooperation as a team. Attributions were coded as internal (coded 1) if the participant's response included reference to their skill or strategy, and external (coded 0) if they made reference to something outside of their locus of control, such as the skill of the other team. In regard to the serious variable, participants responded with very (coded 3), somewhat (coded 2), or not at all (coded 1). If the participant responded to the question of why they won or lost by making reference to their teams' strategy or cooperation, then the variable for cooperation was coded as 1; otherwise it was coded 0.

Table 5

Descriptive Statistics for Questionnaire Variables

Variable	*M*	SD
Social Competence	2.21	1.20
Liked by others	2.29	1.37
Sociality	2.40	1.27
Leadership	2.70	1.26
Respected by others	2.36	1.32
Social support	2.40	1.19

Note. The range was 1 (most or best) to 5 (least or worst).

Table 6

Correlations among Questionnaire Variables

	Competence	Liked	Social	Leader	Respected	Support
Competence	1	.88	.81	.63	.81	.81
Liked		1	.80	.73	.85	.78
Social			1	.77	.78	.61
Leader				1	.78	.45
Respected					1	.69
Support						1

All are significant at $p<.001$

Responses were coded as missing if the participant did not answer the question or if the answer did not address the question; 7.6% of responses were missing. To assess reliability, all responses were coded separately by two individuals. Across coder correlations for internal/external attributions were significant for both the within, $r(37)=.60$, $p<.0001$, and between, $r(36)=.80$, $p<.0001$, tournaments. The across coder correlations were also high for serious for both the within, $r(39)=.90$, $p<.0001$, between, $r(42)=.87$, $p<.0001$, tournaments. The across-coder correlation for cooperation was similarly high, $r(36)=71$, $p<.0001$. For all three variables, the PIs codes were used in the regression analyses.

Regression Analyses

To further explore the pattern of hormone responses during the competitions, a series of 16 regression (2 tournaments, with four times each, separate by hormone type) were run. Several variables are of particular theoretical importance; specifically, outcome, attributions, expectations, cooperation, seriousness, and leader. Separate regressions are run for win and rank as these may differentially predict hormone measures based on competition type. The outcome variables, leader and the interaction of outcome by leader are included in every equation based on the finding that desire for status/power influences hormone responses to winning and losing (Schultheiss et al., 1999). Other variables are only entered at specific times, such as expectations only time 2, attributions only time 3, cooperation and serious are only time 4.

Several control variables were entered in each equation; these are relationship status, stress, history (i.e., activities or substances that could affect hormone levels), and previous hormone values. Previous intra-tournament hormone values and mood variables were included as controls, and entered in the respective equations. Initially, I included all respective vigor and mood disturbance variables at the time of assessment, and in all equations subsequent thereto. For example, at time 3, vigor 1, vigor 2 and vigor 3 appeared in the equation. However, to conserve degrees of freedom, I only retained those vigor or mood disturbance variables that where significant in at least once in the set of equations.

All values were standardized with a mean of zero and standard deviation of 1. For the theoretically important variables, such as leader, rank, win, expectations, attributions seriousness and cooperation, I corrected the overall alpha level by dividing the experimentwise alpha = .05 by the number of theoretically important variables in the equation. The final regression equations are provided in appendix 5.

Testosterone

Within-Group Tournament

Time 1. The overall model for rank was not significant, $F(8,30)=1.26$, $p>.25$, $R^2=.26$, MSE= .94. None of the predictors for the rank model were significantly related to testosterone values (*ps*>.1).

The overall model for win was not significant, $F(8,30)=1.35$, $p>.25$, $R^2=.27$, MSE= .93. None of the predictors for the win model were significantly related to testosterone values (*ps*>.1).

Time 2. The overall model for rank was significant, $F(11,27)=2.33$, $p<.05$, $R^2=.49$, MSE= .72. For the rank model, two control variables were significant: testosterone at time 1, $\beta=.60$, $p<.01$, and confounding history, $\beta=-.40$, $p<.05$. Otherwise, higher testosterone at time 2 was associated with higher expectations for team performance, $\beta=.62$, $p<.01$.

The overall model for win was significant, $F(11,27)=2.73$, $p<.05$, $R^2=.53$, MSE= .66. For the win model, two controls were significant: testosterone at time 1, $\beta=.59$, $p<.01$, and confounding history, $\beta=-.42$, $p<.05$. Otherwise, higher testosterone at time 2 was associated with higher expectation for team performance, $\beta=.61$, $p<.01$.

Time 3. The overall model for rank was not significant, $F(15,23)=1.15$, $p>.25$, $R^2=.43$, MSE= .94. For the rank model, none of the predictors were significantly related to testosterone (*p*s>.05).

The overall model for win was not significant, $F(15,23)=1.17$, $p>.25$, $R^2=.43$, MSE= .94. For the win model, none of the predictors were significantly related to testosterone (*p*s>.05).

Time 4. The overall model for rank was highly significant, $F(15,23)=11.19$, $p<.0001$, $R^2=.88$, MSE= .19. For the rank model, higher testosterone at time 4 was associated several control variables: committed relationship status, $\beta=.31$, $p<.01$, testosterone at time 2, $\beta=.74$, $p<.0001$, vigor at time 1, $\beta=-.53$, $p<.01$, vigor at time 3, $\beta=.75$, $p<.0001$, mood disturbance at time 1, $\beta=-.62$, $p<.0001$, and mood disturbance at time 4, $\beta=.45$, $p<.01$. The fluctuating relations with vigor and mood disturbance across time might be due to the high correlations among the vigor and mood disturbance variables and thus suppression effects. In any case, the attribution variable indicated that external attributions were associated with higher testosterone at time 4, $\beta=-.31$, $p<.05$, which after the alpha correction this becomes non-significant.

The overall model for win was highly significant, $F(15,23)=11.31$, $p<.0001$, $R^2=.88$, MSE= .20. For the win model, several of the control variables were significant: committed relationship status, $\beta=.25$, $p<.05$, testosterone at time 2, $\beta=.75$, $p<.0001$, vigor 1, $\beta=-.51$, $p<.01$, vigor 3 $\beta=.71$, $p<.001$, mood disturbance 1, $\beta=-.64$, $p<.001$, and mood disturbance 4, $\beta=.46$, $p<.01$. Otherwise, higher testosterone at time 4 was associated with external attributions, $\beta=-.38$, $p<.01$, which after the alpha correction becomes non-significant.

Between-Group Tournament

Time 1. The overall model for rank was significant, $F(8,30)=2.48$, $p<.05$, $R^2=.40$, MSE= .76. For the rank, two controls were significant: vigor 1, $\beta=-.45$, $p<.05$, and mood disturbance 1, $\beta=-.59$, $p<.01$.

The overall model for win was significant, $F(8,30)=2.63$, $p<.05$, $R^2=.41$, MSE= .74. For the win model, two controls were significant: vigor 1, $\beta=-.40$, $p<.05$. and mood disturbance 1, $\beta=-.54$, $p<.01$.

Time 2. The overall model for rank was not significant, $F(13,25)=1.32$, $p>.25$, $R^2=.40$, MSE= .90. For the rank model, three controls were significant; vigor 1, $\beta=.73$, $p<.05$, vigor 2, $\beta=-.63$, $p<.05$, and testosterone 1, $\beta=.45$, $p<.05$.

The overall model for win was not significant, $F(13,25)=1.35$, $p>.25$, $R^2=.41$, MSE= .89. For the win model, three controls were significant; vigor 1, $\beta=.83$, $p<.05$, vigor 2, $\beta=-.66$, $p<.05$, and testosterone 1, $\beta=.47$, $p<.05$.

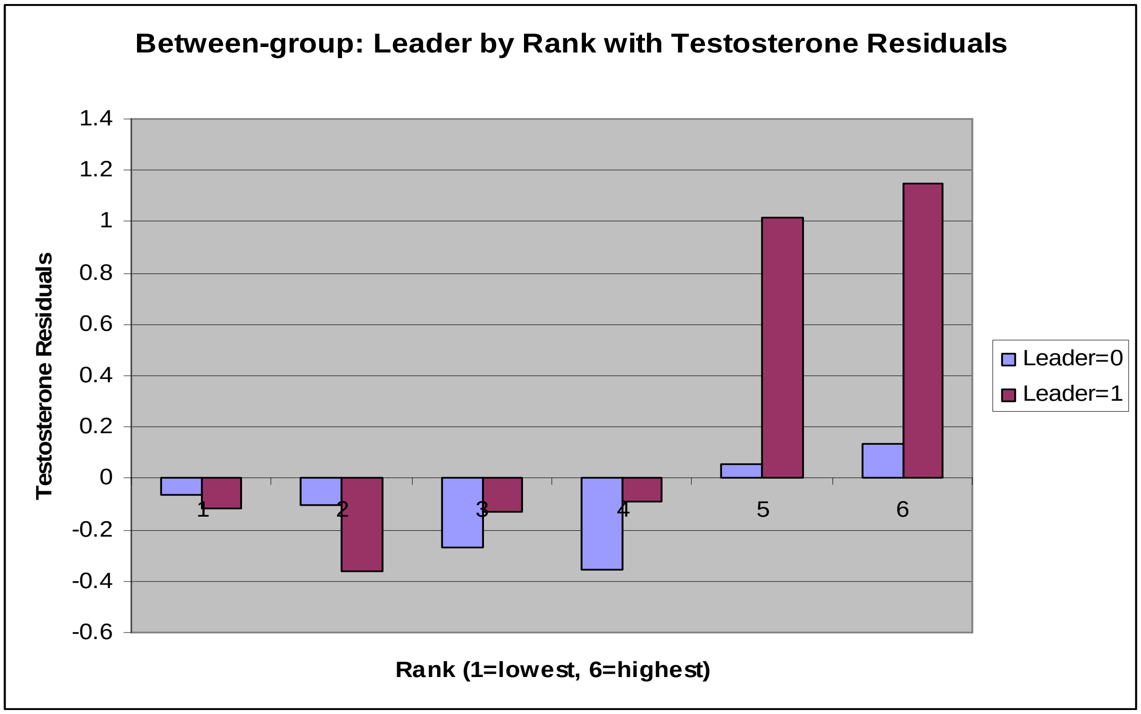
Time 3. The overall model for rank was significant, $F(17,21)=2.78$, $p<.05$, $R^2=.69$, MSE= .56. For the rank model, four of the controls were significant: testosterone at time 2, $\beta=.89$, $p<.001$, confounding history, $\beta=-.48$, $p<.01$, vigor 2, $\beta=.87$, $p<.05$, and mood disturbance 2, $\beta=.80$, $p<.01$. Otherwise higher testosterone was associated with external attributions, $\beta=-.49$, $p<.05$, which become non-significant with alpha correction, and lacking seriousness, $\beta=-.77$, $p<.001$.

The overall model for win was not significant, $F(17,21)=2.14$, $p>.05$, $R^2=.63$, MSE= .66. For the win model, three of the controls were significant: testosterone at time 2, $\beta=.73$, $p<.01$, confounding history, $\beta=-.41$, $p<.05$, and vigor 2, $\beta=.71$, $p<.05$. Otherwise higher testosterone was associated with external attributions, $\beta=-.44$, $p<.05$, and increasing seriousness, β=.69, p<.01, both of which become non-significant after alpha correction.

Time 4. The overall model for rank was significant, $F(16,22)=10.03$, $p<.0001$, R^2=.88, MSE= .20. For rank model, three controls were significant: testosterone at time 2, β=.50, p<.01, mood disturbance 1, β=-.85, p<.01, and mood disturbance 2, β=.79, p<.01. Otherwise higher testosterone was associated with a lack of cooperation, β=-.24, p<.05, increases in rank, β=.32, p<.01, and increases in the interaction of leader by rank, β=.72, p<.0001. After alpha correction of the theoretically important variables, only the leader by rank interaction remains significant.

To follow up on the significant leader by rank interaction, I dichotomized the leader variable, coding individuals above the mean as 1 and those below it as 0. Residualized means are plotted in Figure 1. As shown in the figure, the two highest ranking men showed higher testosterone than the other men, but only if they were above average on the leader variable. To contrast these two highest ranks, a new variable–coded 1 for individuals in the two highest ranks and with a leader score of 1 and 0 for all others – was created and used to predicted residual testosterone values. The contrast was significant $t(37)= 5.49$, p<.0001. Another regression predicting residual testosterone from the contrast variable and the leader by rank interaction, revealed that only the contrast variable was significant, $t(34)=2.68$, p<.05. This last regression indicates that the original leader by rank interaction was driven largely by the two highest ranking (within their between group match) men with above average leader scores.

Figure 2: *Testosterone Residuals by Rank Separate for Leader*



The overall model for win was significant, $F(16,22)=3.35$, $p<.01$, $R^2=.70$, MSE= .50. However, none of the predictors were significantly related to testosterone (ps>.05).

Cortisol

Within-Group Tournament

Time 1. The overall model for rank was not significant, $F(8,30)=1.93$, $p>.1$, $R^2=.34$, MSE= .84. For the rank model, increases in cortisol were associated with decreases in leader, $\beta=-.37$, $p<.05$, which becomes non-significant after alpha adjustment.

The overall model for win was not significant, $F(8,30)=2.04$, $p>.1$, $R^2=.35$, MSE= .82. For the win model, one control was significant, confounding history, $\beta=.37$, $p<.05$. Otherwise, increases in cortisol were associated with decreases in leader, $\beta=-.29$, $p<.05$, which becomes non-significant after alpha correction.

Time 2. The overall model for rank was significant, $F(11,27)=4.17$, $p<.01$, $R^2=.63$, MSE= .52. For the rank model, two of the control variables were significant: cortisol at time 1, $\beta=.54$, $p<.01$, and non-committed relationship status, $\beta=-.40$, $p<.05$. Otherwise, higher cortisol was associated with increases in expectation of individual performance, $\beta=.72$, $p<.01$.

The overall model for win was significant, $F(11,27)=4.20$, $p<.01$, $R^2=.63$, MSE= .52. For the win model, the same two control variables were significant: relationship status, $\beta=-.40$, $p<.05$, and cortisol at time 1, $\beta=.54$, $p<.01$. Otherwise, higher cortisol was associated with increases in expectation of individual performance, $\beta=.73$, $p<.01$.

Time 3. The overall model for rank was not significant, $F(15,23)=3.39$, $p>.05$, $R^2=.69$, MSE= .54. For the rank model, two control variables were significant, cortisol at time 1, $\beta=-.42$, $p<.05$, and cortisol at time 2, $\beta=.89$, $p<.0001$.

The overall model for win was not significant, $F(15,23)=3.56$, $p>.05$, $R^2=.69$, MSE= .50. For the win model, three control variables were significant: cortisol at time 1, $\beta=.-47$, $p<.05$, cortisol at time 2, $\beta=.92$, $p<.0001$, and confounding history, $\beta=.33$, $p<.05$.

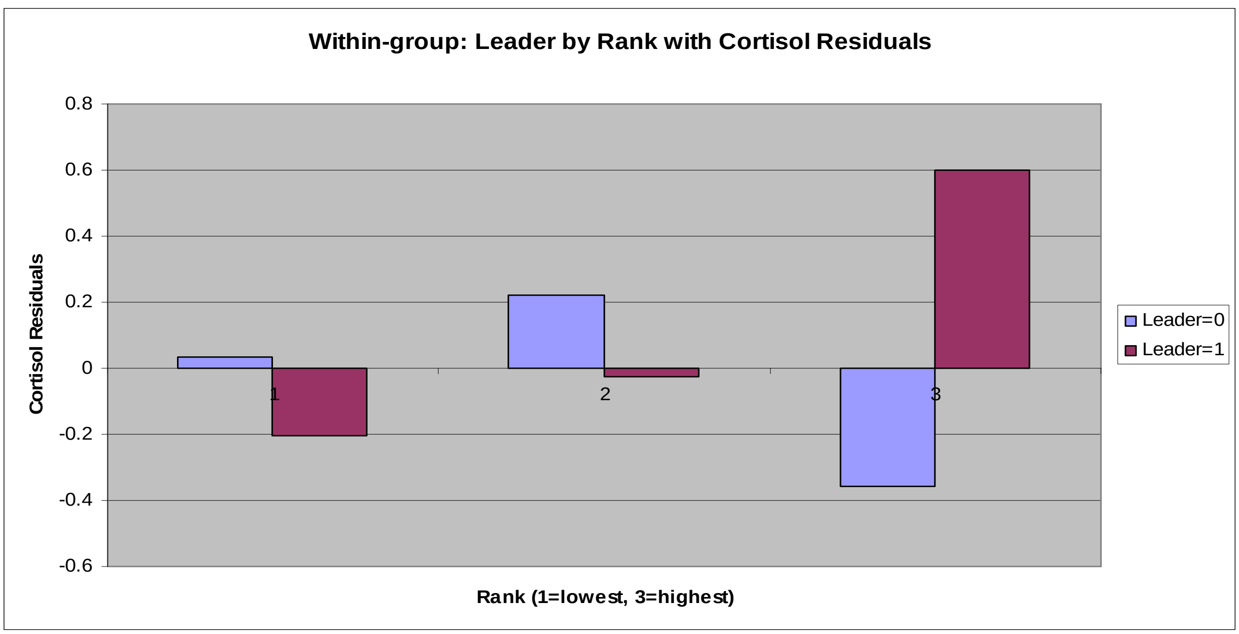
Time 4. The overall model for rank was significant, $F(15,23)=7.89$, $p<.0001$, $R^2=.84$, MSE= .27. For the rank model, one control was significant, cortisol at time 1, $\beta=.34$, $p<.05$. Otherwise, increases in cortisol were associated with internal attributions, $\beta=.29$, $p<.05$, which becomes non-significant with alpha correction, and increases in the leader by rank interaction, $\beta=.38$, $p<.01$.

The overall model for win was highly significant, $F(15,23)=9.00$, $p<.0001$, $R^2=.85$, MSE= .24. For the win model, three control variables were significant: cortisol at time 1, $\beta=.44$, $p<.01$, cortisol at time 2, $\beta=.26$, $p<.05$, and mood disturbance 1, $\beta=-.32$,

$p<.05$. Otherwise, higher cortisol was associated with increases in leader, $\beta=.19$, $p<.05$, which becomes non-significant with alpha correction, losing the match, $\beta=-.74$, $p<.01$, and increases in the leader by win interaction, $\beta=.28$, $p<.001$.

To follow up on the significant leader by outcome interactions, I used the dichotomized leader variable; residualized means are provided in Figure 2. Then I ran a regression model predicting cortisol residuals from the interaction of leader by rank, including all pairwise comparisons, adjusted for multiple comparisons using Tukey-Kramer. The only significant difference among means was for the highest rank, such that cortisol was higher for those above the mean on the leader variable, t(33)=3.50, p<.05.

Figure 3: *Cortisol Residuals, Leader by Rank Follow Up.*



Between-Group Tournament

Time 1. The overall model for rank was not significant, $F(8,30)=.37$, $p>.5$, $R^2=.09$, MSE= 1.15. For the rank model, none of the predictors were significantly related to cortisol (*p*s>.1).

The overall model for win was not significant, $F(8,30)=.37$, $p>.5$, $R^2=.09$, MSE= 1.15. For the win model, none of the predictors were significantly related to cortisol (*p*s>.1).

Time 2. The overall model for rank was not significant, $F(13,25)=1.89$, $p>.1$, $R^2=.50$, MSE=.77. For the rank model, one control was significant, cortisol at time 1, $\beta=.41$, $p<.05$.

The overall model for win was not significant, $F(13,25)=1.39$, $p>.1$, $R^2=.42$, MSE= 88. For the win model, one control was significant cortisol at time 1, $\beta=.43$, $p<.05$.

Time 3. The overall model for rank was not significant, $F(17,21)=.76$, $p>.5$, $R^2=.38$, MSE= 1.12. For the rank model, increases in cortisol were associated with decreases in the appraisal of team performance, $\beta=-.58$, $p<.05$, which becomes non-significant with alpha correction.

The overall model for win was not significant, $F(17,21)=.81$, $p>.5$, $R^2=.40$, MSE= 1.09. For the win model, increases in cortisol were associated with decreases in the appraisal of individual performance, $\beta=.61$, $p<.05$, which becomes non-significant with alpha correction.

Time 4. The overall model for rank was not significant, $F(16,22)=1.41$, $p>.1$, $R^2=.51$, MSE= .85. For the rank model, one control was significant, cortisol at time 3, $\beta=.44$, $p<.05$.

The overall model for win was not significant, $F(16,22)=1.62$, $p>.1$, $R^2=.54$, MSE= .79. For the win model, two controls were significant, cortisol at time 3, $\beta=.45$, $p<.05$; and confounding history, $\beta=.39$, $p<.05$.

DISCUSSION

The current study was the first to experimentally contrast the testosterone and cortisol responses of young men across within-group and between-group competitive videogame tournaments. As such it provides a contrast to previous studies that have focused largely on dyadic or individual based competition. I found that the mean hormonal changes, without adjusting for potential confounds or individual differences, reflected increases in cortisol across both competitions. The lack of omnibus findings for testosterone was not unexpected, as individual differences were predicted to moderate any win effects for this hormone. Indeed, the variable leader, when other effects are controlled, interacted with rank; specifically, individuals who were above average on this variable and ranked first or second showed an increase in testosterone for the between-group match and cortisol for the within-group match.

The significant results are described below beginning with a contrast of within- and between-group differences. In general, the between-group tournament differed from the within-group tournament in that testosterone was more consistently associated with the predictors for the former and with cortisol for the latter. The implication is that the between-group competition elicited a more competitive hormonal response and the within-group competition a more stress-related response.

Theoretically Important Variables

Win effect: Leader and Rank.

The most theoretically important contrast of the within- and between-group matches was for the time point 30 minutes after the competition, when I expected a win effect. With the control of confound and moderator variables, the interaction of leader by rank was highly significant for testosterone for the between-group tournament but not for the within-group match. Contrasts showed that for the top two ranks and only for those above the mean on the leader variable (discussed below), testosterone increased significantly following the tournament. The significant leader by rank interaction is not the team-win effect I predicted, however. This is because for the between-group tournament not all of the highest ranked players actually won the match. Instead, the effect appears to reflect an individual win effect based on relative status across both teams.

In contrast, 30 minutes after the within-group tournament, the leader by rank interaction was significant for cortisol. Here, the winner of the match showed cortisol increases for competitors above the mean on the leader variable. For men who appear to prefer status and when competing within his coalition, winning may be stressful. One possibility is that the distress might have reflected a concern about their ability to form a cohesive in-group, that is, inflicting a loss on teammates–though necessary to assert "dominance"–may have the potential trade-off of making these other men less likely to cooperate together as a team. Follow-up studies are needed to fully explore this possibility.

The leader variable was comprised of six items from a self-report questionnaire regarding the participants' general, social competence, sociability, leadership, social support, respect by others, and how much people like them. These components were meant to reflect several aspects indicative of a coalitional leader. First, whether they are interested and able in social situations. Second, whether they feel that they have leadership abilities, indicating that they are not averse to the responsibilities of higher status. And third, whether they are supported, liked, and respected by those around them, presumably indicating ability in social leadership. That the measure was self-reported and measured only once may be a weakness of this study. Moreover, this is the first study in which the leader variable was used; its reliability is yet to be determined. However, more recent studies have supported the validity of using this type of variable. Edwards, Wetzel and Wyner (2006) found that change in testosterone from before to after a soccer game was highly correlated with status among teammates, and effective communication on the field. Moreover those with status feel more socially connected with teammates.

In the context of the literature regarding hormones and competition, the hypothesis that explicit trait-like differences measured in a questionnaire may moderate the relationship between hormone responses to competition is novel.

The leader variable may capture some aspects of implicit-power motivation (i.e., Schultheiss et al., 2006), but this remains to be firmly established. In any case, the leader by rank interaction suggested that the same construct predicted increase in testosterone following strong performance (1^{st} or 2^{nd} place) during the between-group match and increases in cortisol following strong performance during the within-group match. It maybe that coalitional competition requires moderate levels of both personalized and socialized power motivation. Specifically, dominance striving must be constrained to some extent when competing with in-group members, and too strong of a performance in these contexts may be stressful to would-be leaders, because winning too solidly comes with the risk of alienating teammates, as I noted. In other words, men who are striving for social leadership face trade-offs in terms of needing to assert dominance within the in-group but risking losing support of in-group members if this is done too strongly. This should not be an issue for the between-group competition, and thus the same winner effect found by Wirth et al. (2006); they did not include a within-group manipulation.

Seriousness.

Previous research suggests that if a competitor does not take the contest seriously, they will not show a testosterone challenge response (Booth et al., 1989; Mazur et al., 1992; Salvador et al., 1987). In partial support, for the between-group but not the within-group competition, men who stated that they took the competition seriously had higher testosterone levels immediately after the tournament. However, 30 minutes after the tournament–when the challenge response is typically found–seriousness was not significantly associated with increases in testosterone levels. To my knowledge other studies did not assess seriousness at more than one time point, it maybe that seriousness is only important immediately after the match.

Attributions

Attributing a contest outcome to an internal source is thought to mediate the relation between winning and testosterone increases, such that testosterone should increase when winners attribute their success to internal factors, such as their skills, as contrasted with external factors, such as luck (Gonzalez-Bono et al., 2000; Serrano, Salvador, Gonzalez-Bono, Sanchis & Suay, 2000). In this sample, there were no differences between attributions across ranks, that is, most of the contestants made internal attributions regarding the outcome. Those men who made external attributions, however, had higher testosterone levels for immediately after and thirty minutes after, for the between-group and within-group tournaments, respectively. For the within-group competition, internal attributions were associated with higher cortisol levels thirty minutes after the competition. I am reluctant to offer substantive interpretation of these results, because none of them were significant with the alpha corrections.

Expectations and appraisal.

I anticipated that expecting to perform well and positively appraising performance would be associated with higher testosterone before the between-group tournament, more so than for the within-group tournament, reflecting increased competitiveness. For the between-group tournament, there was no significant association between expectations, appraisal and testosterone, but there was for cortisol. Higher cortisol levels were found for individuals who thought their team would perform poorly, indicating stress in anticipation that their team was not up to the challenge.

For the within-group tournament only, men who expected their teammates to play well had higher testosterone levels than did other men immediately before the match. So that when one perceives that the competition against teammates will be tough, despite being in-group members, testosterone still increases right before the competition. Moreover, men who expected their individual performance to be strong had higher cortisol levels. The higher cortisol may have reflected greater focus or concerns about potentially alienating teammates and thus possibly damaging in-group cohesion. However, because in general the participants agreed on intragroup skill ranking, I expect that they knew how well their teammates would play and whether they had a chance to win or not. Therefore, it seems logical to conclude that expecting ones teammates to perform well suggests they believed they were not likely to win. The paradox is in that their testosterone levels were still higher before the match. I would have expected lower levels, as if withdrawing from the competition. One possibility is that they still wanted to play well, because they were still part of the team for the between-group match. This would be consistent with Lever's (1978) finding that boys reported that doing well in front of one's teammates was important to them.

Control Variables

Relationship Status

Being in a committed relationship was associated with higher testosterone levels at the critical time point, that is, thirty minutes after the match ended, but only for the within-group tournament. Other studies in monogamous societies have shown that men in committed relationships have lower basal testosterone levels (Burnham et al. 2003), which led me to expect lower testosterone levels for these men throughout both tournaments. The positive effect in the context of a within-group competition may reflect more adequate social coping resources buffering these men from pre-event competitive suppression of testosterone. In line with this assertion, immediately before the within-group tournament men who were not in a committed relationship had higher cortisol levels, but this effect did not survive the alpha correction and thus needs to be interpreted with caution. However, it may be that men in a committed relationship simply respond more competitively to intragroup competition.

Mood

Finally, for both the within- and between-group competitions, the relations between testosterone levels and mood fluctuated, likely due to statistical suppression effects between the mood variables. It may also be that mood is not consistently related to competition related changes in testosterone. Previous research, in which the Profile of Mood States (POMS) was used, as in this study, has revealed an inconsistent relation between hormones and mood (Gonzalez-Bono et al., 2000; Gonzales-Bono et al., 1999; Gonzalez-Bono et al., 2002). This might be due to the complex nature of mood states across individuals and the varying competitive contexts that have been assessed in this literature. Though the general expectation is that testosterone should positively relate to vigor and negatively relate to overall mood disturbance, but this was not consistently the case in this study.

Other Variables

Inconsistent with some previous research, state and trait anxiety levels were not associated with hormone values (Filiare et al., 2001). This suggests that the controlled laboratory setting and the videogame contest invokes less anxiety, in contrast to competitive sporting events, such as Judo, in which anxiety has been correlated to hormone levels. Moreover, personality variables were not significantly related to hormone values. As far as I know, this is the first study to include the Big-Five personality measure in the challenge paradigm. Most of the participants were above average on these measures and the corresponding restriction of range may have obscured any relation between personality and hormonal responses to competition. It is also possible that personality, as measured by the Big-Five (Goldberg, 1993) does not moderate men's responses to this form of competition.

Conclusions

I found that in the context of a coalition, leadership, social interest and ability, and positive social standing among peers differentially predicted a rank effect for within- and between-group competitions. Men high on self-reported social leadership traits and who performed well showed the predicted testosterone increase for the between-group competition and a cortisol increase for the within-group competition. Although a between-group team effect did not emerge (i.e., a win effect for all team members), there were consistent differences in hormone response comparing the between- and within-group matches; testosterone was related to performance in the between-group match and cortisol in the within-group match. Future studies should control the rank-related feedback provided during the game and examine if a longer affiliation period among teammates will produce a team-based win effect.

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Appendix 1: Consent Form

INFORMED CONSENT

PROJECT BACKGROUND: In this project, I understand that I will be providing data through collection of saliva and a series of questionnaires, and that these data may be published. I understand that I will be anonymous after the preliminary questionnaire in completed and all personal identifiers will be removed at the end of the study. Therefore it will not be possible to identify me in data publication or otherwise. I am 18 years old, or older. This study is being directed by Jon Oxford under the supervision of David C Geary, Department of Psychological Sciences, at the University of Missouri-Columbia.

PURPOSE: The objective of this study is to follow the body chemistry and moods of participants as they engage in simulated competition (PC Games).

VOLUNTARY: I understand that this study is voluntary. I may refuse to answer any question, withdraw from participation, and/or request the exclusion of written materials as well as saliva from analysis at any time without any penalty or loss of benefits to which I would be otherwise entitled.

WHAT DO YOU DO? I will take part in several practice sessions in a gaming computer lab to rehearse for tournaments, and then participate in a series of matches against other teams and against my own teammates. In the process, saliva will be provided for assay; questionnaires and other written measures will also be provided, some pertaining to questions about feelings and personality that may make me uncomfortable. I also understand that I need to be punctual and reliable as my team and others will not be able to run the experiment without me.

BENEFITS: I will take part in 5 sessions: three practice sessions and two tournaments. For each session I will receive 2 credits for Psychology 1000, totally 10 credits. I realize that there are other experiments that I could take part in to acquire the credits I need for my class, but I am choosing to participate in this one. If I, or my team, take first place a tournament, I will receive $45, or $15 for any other place.

RISKS: This project does not involve any known risks.

CONFIDENTIALITY: My confidentiality will be maintained in that my name will not appear on the survey or in the published study itself. My answers are entirely confidential, and will not be revealed to anyone other than the researchers conducting the study.

INJURY STATEMENT: It is not the policy of the University of Missouri to compensate human subjects in the event the research results in injury. The University of Missouri does have medical, professional and general liability self-insurance coverage for any injury caused by the negligence of its faculty and staff. Within the limitations of the laws of the State of Missouri, the University of Missouri will also provide facilities and medical attention to subjects who suffer injuries while participating in the research projects of the University of Missouri. In the event you have suffered injury as the result of participating in this research project, you are to immediately contact the Campus Institutional Review Board Compliance Officer at (573) 882-9585 and the Risk Management Officer at (573) 882-3735 to review the matter and provide you further information. This statement is not to be construed as an admission of liability.

Your efforts are greatly appreciated. If you have any questions regarding the study, please contact Jon Oxford at (573) 884-1563. If you have questions regarding your rights as a participant in research, please feel free to contact the Campus Institutional Review Board at (573) 882-9585.

Name:______________________________________ Date:_______________________

Appendix 2: Debriefing

Debriefing Form

Thank you for your participation. The following is a brief description of the theory and purpose of the study. Sexual selection is a special form of Natural selection. According to Darwin, the adaptations (e.g., traits) that result from Natural selection are those that allowed an individual to survive the local ecology relatively better than conspecifics (e.g., others of the same species), whereas sexual selection resulted in adaptations that allowed individuals an advantage in competing for mates. Humans are thought to be largely result of sexual selection, as ecological selection is thought to have been weak in hominins (e.g., great apes, hominids and humans). Discussion of the fossil record, primate morphology, cultural ethnographies, and comparative animal studies that gave rise to the modern understanding of human evolution are beyond the scope this form, what is relevant is that humans are thought to have evolved in male-linage kinship groups, and mate competition took the form of group-on-group competition, for example warfare or tribal raiding. The developmental literature on sex differences in social behaviors shows that human's behavioral and motivational systems are dimorphic and reminiscent of patterns suggested by theory.

The current study was designed to assess salivary testosterone and cortisol level differences in competition within ones' group and between groups. Based on evolutionary considerations, the hypothesis was that testosterone (e.g., the primary male sex hormone thought to be related to competitive inclinations in males) and cortisol (e.g., primary stress hormone in humans) levels are lower when competing within ones' group, so that they are less competitive and more cooperative, than between groups. This is based on the assumption that male-male competition during human evolution included a very important coalitional (e.g., a group of individuals working together toward a common goal) component. The social dynamics that correspond with competition between groups and cooperation within groups is thought to be the key variable that is responsible for uniquely human traits, brain-size and sex differences in social cognition. We were testing a proposal that human males have evolved motivational and behavioral predispositions that bias them toward cooperative in-group and competitive out-group dynamics. In addition, moods and attributions were examined to support or refute evidence currently in the literature on the psychological correlates of testosterone and cortisol. All information is kept strictly confidential: your name will not be associated in any way with your responses, and you will not be identified in any publication. This project is directed by Jon Oxford, and is conducted under the supervision of Dr. David Geary, Department of Psychological Sciences, University of Missouri-Columbia. If you have questions about the study you can contact us at (573) 884-1563. If you have any concerns about this project, you can contact Michelle Reznicek of the Institutional Review Board of the University of Missouri at (573) 882-1563.

Appendix 3: Preliminary Questionnaire

ID Creation Coversheet

1. Do not turn the page until instructed to do so.
2. When instructed, please provide identification information that you will use throughout this experiment:
   a. In the form of "Screen name [Team name]"
   b. Can not exceed 15 characters.
   c. For example:
      i. Hero [Rogues]
      ii. Blackat [Sapiens]

ID: ____________________[________________________]
Screen name Team name

3. Now Stop.

Part 1: Bio **BACKGROUND QUESTIONNAIRE**

1.Age: __________________ Date:_______________

2.Team name:

____

3.Screen name:

____

4.First name: ________________________________Last Name

:___________________

5.Email address:

____

6.Phone numbers:

____________________________Cell:_________________________

7. Year in school (Circle One):		**Freshman Sophomore Junior Senior**			
8. Are you in a Committed Relationship?		**Yes No**			
Parents Education level:	9. Mom:	**High school**	**College**	**Graduate**	
	10. Dad:	**High school**	**College**	**Graduate**	
Rate your past experiences: "1" is the Most or Best and "5" is none or none at all.					
11. PC Gaming?		1	2	3	4 5

12. Team competition of any sort (Academic, Athletic etc.)?	1	2	3	4	5
13. Your skill at Unreal Tournament 2004?	1	2	3	4	5
Rate yourself: "1" is the Most or Best and "5" is none or not at all.					
14. Dominance as a personality trait?	1	2	3	4	5
15. Social competence?	1	2	3	4	5
16. Are you well liked by others?	1	2	3	4	5
17. Are you social by nature?	1	2	3	4	5
18. Are you a leader?	1	2	3	4	5
19. Do people respect you?	1	2	3	4	5
20. Amount of social support?	1	2	3	4	5

Appendix 4: Timed Questionnaires

T1 – VIAL NUMBER________

Date:______________________
__

ID:______________________________[_________________________________]			
	Screen name	*Team name*	

Please indicate ***how many*** of the following items describe your recent history, by circling one of the numbers that follows the list.

Do not indicate which items.

Activity:	Time prior to now:
Eat a major meal	1 hour
Eat dairy products	30 minutes
Consumed acidic or high sugar foods	1 hour
Brushed your teeth	2 hours
Engaged in sexual activity	24 hours
Consumed alcohol	48 hours
Taken medication that is over the counter	24 hours
Take prescription medicines	24 hours

Please circle one of the following numbers:

1	**2**	**3**	**4**	**5**	**6**	**7**	

	How you feel?	How do you think your team mates feel?	How do you think your opponents are feeling?
Prepared mentally for the match (e.g, simulation, visualized)?	Yes No	Yes No	Yes No
Mentally focused right now?	Yes No	Yes No	Yes No
Skillful as a player?	Yes No	Yes No	Yes No
Competitive?	Yes No	Yes No	Yes No
Integrated with the team?	Yes No	Yes No	Yes No
Affiliative?	Yes No	Yes No	Yes No
Autonomous?	Yes No	Yes No	Yes No
Loyal to the team?	Yes No	Yes No	Yes No
Tough?	Yes No	Yes No	Yes No
Cooperative?	Yes No	Yes No	Yes No
Strategic?	Yes No	Yes No	Yes No
Serious?	Yes No	Yes No	Yes No

Rank the three of you in order starting with the best all at Unreal Tournament 2004:	
1. Best	(Screen name)________________________________
2. Second	(Screen name)________________________________
3. Third	(Screen name)________________________________

2. Have you experienced any unusually stressful event in the last week? Yes No

T2 – VIAL NUMBER________ Date:________________________

ID:______________________[____]
Screen name *Team name*

	How you feel?		How do you think your team mates feel?		How do you think your opponents are feeling?	
1. Prepared mentally for the match (e.g., simulation, visualized)?	Yes	No	Yes	No	Yes	No
2. Mentally focused right now?	Yes	No	Yes	No	Yes	No
3. Skillful as a player?	Yes	No	Yes	No	Yes	No
4. Competitive?	Yes	No	Yes	No	Yes	No
5. Integrated with the team?	Yes	No	Yes	No	Yes	No
6. Affiliative?	Yes	No	Yes	No	Yes	No
7. Autonomous?	Yes	No	Yes	No	Yes	No
8. Loyal to the team?	Yes	No	Yes	No	Yes	No
9. Tough?	Yes	No	Yes	No	Yes	No
10. Cooperative?	Yes	No	Yes	No	Yes	No
11. Strategic?	Yes	No	Yes	No	Yes	No
12. Serious?	Yes	No	Yes	No	Yes	No

13.	How well did you play?	Best	Ok	Poorly	
14.	How well did your team play?	Best	Ok	Poorly	

Rank the three of you in order starting with the best all at Unreal Tournament 2004:	
1. Best	(Screen name)_________________________________
2. Second	(Screen name)_________________________________
3. Third	(Screen name)_________________________________

\

T3 – VIAL NUMBER______

Date:________________________

ID:________________________[____]

Screen name *Team name*

	How you feel?	How do you think your team mates feel?	How do you think your opponents are feeling?
1. Prepared mentally for the match (e.g., simulation, visualized)?	Yes No	Yes No	Yes No
2. Mentally focused right now?	Yes No	Yes No	Yes No
3. Skillful as a player?	Yes No	Yes No	Yes No
4. Competitive?	Yes No	Yes No	Yes No
5. Integrated with the team?	Yes No	Yes No	Yes No
6. Affiliative?	Yes No	Yes No	Yes No
7. Autonomous?	Yes No	Yes No	Yes No
8. Loyal to the team?	Yes No	Yes No	Yes No
9. Tough?	Yes No	Yes No	Yes No
10. Cooperative?	Yes No	Yes No	Yes No
11. Strategic?	Yes No	Yes No	Yes No
12. Serious?	Yes No	Yes No	Yes No

13.	How well did you play?	Best	Ok	Poorly	
14.	How well did your team play?	Best	Ok	Poorly	

Rank the three of you in order starting with the best all at Unreal Tournament 2004:	
14. Best	(Screen name)________________________________
15. Second	(Screen name)________________________________
16. Third	(Screen name)________________________________

17. How seriously did you take the match?

____

____

____

18. Why did you win or lose?

____

____

____

T4 – VIAL NUMBER______

Date:________________________
_

ID:____________________________[____]
Screen name *Team name*

	How you feel?		How do you think your team mates feel?		How do you think your opponents are feeling?	
1. Prepared mentally for the match (e.g., simulation, visualized)?	Yes	No	Yes	No	Yes	No
2. Mentally focused right now?	Yes	No	Yes	No	Yes	No
3. Skillful as a player?	Yes	No	Yes	No	Yes	No
4. Competitive?	Yes	No	Yes	No	Yes	No
5. Integrated with the team?	Yes	No	Yes	No	Yes	No
6. Affiliative?	Yes	No	Yes	No	Yes	No
7. Autonomous?	Yes	No	Yes	No	Yes	No
8. Loyal to the team?	Yes	No	Yes	No	Yes	No
9. Tough?	Yes	No	Yes	No	Yes	No
10. Cooperative?	Yes	No	Yes	No	Yes	No
11. Strategic?	Yes	No	Yes	No	Yes	No

12. Serious?	Yes No	Yes No	Yes No

13.	How well did you play?	Best	Ok	Poorly	
14.	How well did your team play?	Best	Ok	Poorly	

Rank the three of you in order starting with the best all at Unreal Tournament 2004:	
1. Best	(Screen name)___________________________________
2. Second	(Screen name)___________________________________
3. Third	(Screen name)___________________________________

Appendix 5: Regression Equations for Testosterone and Cortisol

I. Testosterone Equations:

1. Testosterone Between (Rank)

Time	Int	T1	T2	T3	V1	M1	V2	M2	rel	Stress	Hist	Wp/Dp	Wtp/Dtp	att	ser	coop	Leader	Rb	LxR
T1 =	.01				-.45*	-.59**			.07	.12	.06						0.31	-.14	-.06
T2 =	.02	.43*			.73*	.61	-.63*	-.49	-.20	.09	.09	.06	-.03				.14	.15	-.14
T3 =	-.01	.23	.89**		-.36	-.45	.87*	.80*	.04	-.09	-.48**	-.03	.18	-.49*	.77***	-.17	-.02	.09	.43
T4 =	.01	.22	.50**	.07	-.08	-.85**	.17	.79**	-.05	-.01	.19			.22	-.15	-.24*	-.04	.32**	.72***

2. Testosterone Between (Win)

Time	Int	T1	T2	T3	V1	M1	V2	M2	rel	Stress	Hist	Wp/Dp	Wtp/Dtp	att	ser	coop	Leader	Win	LxW
T1 =	-.75				-.40*	-.54**			.03	.09	.09						.29	-.53	.16
T2 =	-.14	.47*			.83*	.79	-.66*	-.52	-.18	.03	.04	.08	-.05				.02	.44	-.17
T3 =	.11	.22	.73**		-.47	-.36	.71*	.57	.04	-.01	-.41*	-.01	.09	-.44*	.69**	-.13	-.04	-.05	.02
T4 =	-.17	.13	.37	.21	-.33	-.63	.12*	.23	.07	.18	.32			.17	-.34	-.19	.07	-.09	.08

3. Testosterone Within (Rank)

Time	Int	Time1	Time2	Time3	V5	M5	V7	M8	rel	Stress	Hist	Wp/Dp	Wtp/Dtp	att	ser	Leader	Rw	LxR
T1 =	.01				.11	.20			-.29	-.27	.19					.09	-.02	.07
T2 =	.09	.60**			-.18	-.10			-.17	.02	-.40*	.02	.62**			.14	.21	.20
T3 =	.08	-.33	.46		-.17	-.05	.17		-.15	-.18	.09	-.39	-.29	.04	-.02	.17	.04	.19
T4 =	.04	.18	.74****	.01	-.51**	-.62***	.75****	.45**	.31**	.03	.18			-.31*	.15	.15	-.01	.19

4. Testosterone Within (Win)

Time	Int	T1	T2	T3	V5	M5	V7	M8	rel	Stress	Hist	Wp/Dp	Wtp/Dtp	att	ser	Leader	Win	LxW
T1 =	-.17				.10	.20			-.30	-.28	.19					.06	-.28	.08
T2 =	-.47	.59**			-.20	-.10			-.19	.04	-.42*	.01	.61**			.14	-.45	.23
T3 =	-.31	-.37	.56*		-.14	-.08	.12		-.11	-.22	.14	-.46	-.31	-.13	.02	.14	-.05	.10
T4 =	-.32	.16	.75****	.01	-.51**	-.64***	.71***	.46**	.25**	.01	.21*			-.38**	.18	.13	-.27	.11

II. Cortisol Equations:

1. Cortisol Between (Rank)

Time	Int	T1	T2	T3	V1	M1	V2	M2	rel	Stress	Hist	Wp/Dp	Wtp/Dtp	att	ser	coop	Leader	Rb	LxR
T1 =	.02				-.15	-.17			-.16	.22	.09						-.14	-.01	-.24
T2 =	-.01	.41*			-.14	-.20	.03	.19	-.22	.01	.13	-.02	-.09				-.21	.13	-.48
T3 =	.02	.01	.01		-.26	.22	.25	.01	.01	-.21	-.20	.44	-.58*	.05	.18	.01	-.02	.21	.13
T4 =	.48	.15	.11	.44*	-.53	-.61	.49	.49	.22	.24	.32			.16	.02	.14	.17	-.04	.08

2. Cortisol Between (Win)

Time	Int	T1	T2	T3	V1	M1	V2	M2	rel	Stress	Hist	Wp/Dp	Wtp/Dtp	att	ser	coop	Leader	Win	LxW
T1 =	.43				-.01	-.08			-.16	.11	.06						-.16	.02	-.06
T2 =	.51	.43*			-.08	-.25	.02	.36	-.22	.14	.07	-.05	-.02				-.02	.21	-.11
T3 =	-.13	-.06	.21		-.40	.36	.42	-.19	.09	-.18	-.18	.61*	-.51	.02	.19	.24	.07	-.66	.15
T4 =	-.46	.19	.06	.45*	-.64	-.72	.53	.57	.21	.29	.39*			.21	-.06	.02	.20	-.11	.13

3. Cortisol Within (Rank)

Time	Int	T1	T2	T3	V5	M5	V7	M8	rel	Stress	Hist	Wp/Dp	Wtp/Dtp	att	ser	Leader	Rb	LxR
T1 =	.01				-.11	.25			-.22	.02	.35					-.37*	-.14	-.14
T2 =	-.15	.54**			-.18	-.09			-.40*	-.07	.04	.72**	.02			-.14	-.06	-.04
T3 =	-.07	-.42*	.89****		-.28	.11	.33		.22	.25	.27	-.06	-.19	-.19	-.11	-.23	.03	-.01
T4 =	-.00	.34*	.36	.27	.20	-.32	-.19	.26	.18	.23	-.12			.30*	-.09	.20	.06	.39**

4. Cortisol Within (Win)

Time	Int	T1	T2	T3	V5	M5	V7	M8	rel	Stress	Hist	Wp/Dp	Wtp/Dtp	att	ser	Leader	Win	LxW
T1 =	.82				-.10	.26			-.21	.01	.37*					-.29*	.36	-.21
T2 =	.14	.54**			-.17	-.08			-.40*	-.07	.02	.73**	.02			-.10	-.08	.00
T3 =	.67	-.47*	.92****		-.37	.12	.45		.22	.29	.33*	.04	-.21	-.13	-.11	-.21	-.06	-.06
T4 =	-.54	.44**	.26*	.37	.17	-.32*	-.22	.18	.06	.18	-.11			.24	-.01	.19*	-.74**	.28***