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Review

Coping with competitive situations in humans

Alicia Salvador*

Department of Psychobiology, Faculty of Psychology, University of Valencia, Apartado 22109, 46071 Valencia, Spain

Abstract

The analysis of effects of competitive situations in our species may contribute to acquiring deeper knowledge about the effects of social stress and its relationship with different pathologies. The latest studies indicate that the neuroendocrine response to competition depends more on subjective factors related to the cognitive evaluation of the situation than on the outcome itself. Findings suggest that when subjects cope with a competition, they assess it in such a way that it activates a psychobiological coping response. The pattern of this response may correspond to a predominant active or passive coping strategy, the choice ultimately depending on factors such as the importance of the competition for the subject, the subject's involvement or perceived possibilities of control of outcome or success (e.g. past experience in similar competitions, judge or rank of the opponent), among others. More important than winning or losing is the coping pattern displayed by the subject, which determines the hormonal changes experienced when facing competition and its outcome.

Keywords: Testosterone; Cortisol; Hormones; Active coping; Passive coping; Social stress; Competition; Agonistic interactions; Sympathetic activity; Social status; Animal models; Sports competitions

Contents

Abbreviations: T, testosterone; C, cortisol; HR, heart rate; BP, blood pressure; HPA, hypothalamic–pituitary axis; SNS, sympathetic nervous system.

* Tel.: +34 96 386 4297; fax: +34 96 386 4668.
E-mail address: alicia.salvador@uv.es

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1. Introduction

The combination of diverse factors (genotype, perinatal environment, physical fitness, experience, social support, etc) ultimately determines the way each individual deals with everyday environmental challenges. Nowadays, current research aims to identify how these individual differences contribute to vulnerability or, on the contrary, to resistance to developing pathologies associated with stress.

From an evolutionary point of view, social stress (sometimes called social conflict) is a chronic, recurring factor in the lives of virtually all higher animal species [1]. Its pattern of effects may be qualitatively different from those motivated by other types of stressors, at both behavioral and physiological levels. Social stress may have important pathological repercussions for many species, not only for humans. For this reason, an important effort is being made to find adequate animal models to analyze this topic, which would make it possible to determine its underlying mechanisms and pharmacological treatments [2], in addition to obtaining deeper knowledge of the more convenient coping responses to stressors.

Confrontation among males is a very extended situation in nature. Competition implies that one or more individuals carry out some actions directed at achieving a goal, by confronting another individual or group of the same species motivated by the same goal (e.g. territory, social status). When one individual obtains the victory, the probabilities of success of the others diminish; in both cases, the outcome has consequences for all those involved. Victory in successive agonistic interactions leads to a dominant position, which includes certain behavioral patterns, as well as specific physiological characteristics at central and peripheral levels, whereas defeat leads to a subordinate status with a different pattern. Main differences among dominant and subordinate animals can be established at different levels: behavioral (social and non-social), physiological (weight and size of organs, cardiovascular parameters, temperature, etc), neuroendocrine (hormonal levels and responses), neurochemical (monoamines, amino-acids, receptors, etc), neurological (*c-fos*) and immunological [1–4].

Agonistic interactions, as well as competition for food, water, or mating, have been employed to evaluate the dominant status of pairs or groups of animals in the laboratory. They include a sole, intermittent or chronic dyadic interaction of an individual with another co-specific, although colony or small group models have also been used. On many occasions, a male is confronted with another who is more or less aggressive by strain, weight or size, by specific manipulation (such as previous experience of victory) or by territoriality; the 'resident–intruder' model is very frequent in rodents. Another important dimension concerns the existence of direct or indirect contact during the interaction, that is, physical attack or threat of attack, a combination of both also being possible. Agonistic encounters are the most frequently employed model to analyze repercussions and mechanisms of social stress.

In addition to animal models, another important way to advance the knowledge about the role of individual differences in stress response is by studying appropriate competitive stress situations in humans. This approach is especially relevant from the evolutionary explanations of human depression, specifically from the social competition hypothesis of depression and other formulations related to social rank [5–8]. However, studying human competitions, although outstanding, is not easy, in spite of the recognized competitiveness prevailing in our lives.

During the last 15 years, we have carried out a number of studies on this topic, whose results have allowed us to observe a great variability in the psychophysiological response to competition. In our studies, we have examined the role of different variables (involvement, physical condition, etc), which has contributed to a better understanding of the individual differences in the human response to a competitive situation. Most studies on this topic have been carried out with men; however, recently a few studies have included women. This review will present the main results obtained with these and other variables, and it will be argued that our knowledge about the psychobiological response to competition in humans will benefit from including the data obtained in a wider theoretical background on stress.

2. Effects of agonistic experience and its outcome, victory or defeat, on humans

In the last few decades, the evidence that has been accumulated indicates that a competitive encounter produces hormonal changes, which seem to be moderated by the outcome, victory or defeat, in several mammalian species [9,10]. The relationships between hormones and aggressive or dominant behavior, initially believed to be unidirectional, began to be thought of as reciprocal and bi-directional. In this context, a biosocial status hypothesis was formulated by Mazur [11,12], as a model of status in face-to-face primate groups. This hypothesis argues that primates competing for status show signs directed at maintaining or improving a high status, displaying dominant behavior which could become aggressive but does not

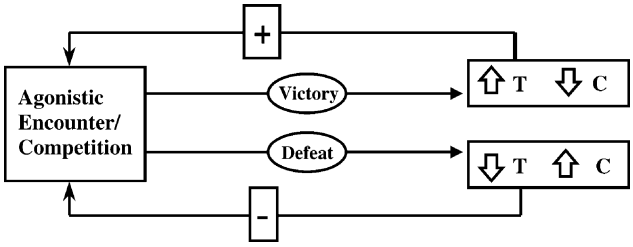

Fig. 1. A representation of Mazur's biosocial status hypothesis based on reciprocal relationships among hormones and behavior [11,12].

necessarily have to. In competitive situations, victory would lead to increases in testosterone (T), whereas defeat would produce decreases, in such a way that in the winners their dominance and tendency to participate in future social encounters would increase; on the contrary, the losers would develop submissive signs, with a diminished tendency to fight. As has been mentioned above, this hypothesis is based on a reciprocal relationship between T and dominant behavior (Fig. 1). Although the main weight of the hypothesis falls on T, reference was also made to cortisol (C) and subjective experiences (discomfort, anxiety, etc).

An important challenge for research in humans is to identify situations that make it possible to study how hormones are related to observable behavior [13]. From an evolutionary approach, the parallelism between sports competitions and competitive or social aggression displayed by individuals of another species has been emphasized [14,15]. Kemper [16] pointed out the relevance of several characteristics of a sports context to study this subject in humans: no pre-established outcome, merit as main criterion of success, and attractiveness derived from the equality of opportunities. In addition, competition is the central focus of sports, it has a limited duration, and its outcome is unambiguous: immediate with clear consequences in the ranking. There is an apparent relationship between performance and reward. All these aspects do not appear as

Table 1
Studies on impact of sports competitions on hormonal variables in men

Sports contests	Men (*n*)	Differences between W and L in hormones	Time interval considered (Samples compared)	Statistics	References
Tennis matches (Doubles)	8	T: ↑ W, ↓ L	1–2 post	(Residual values) binomial test	[17]
Tennis matches (singles)	6 (×6 meets)	Tsal: ↑ W, ↓ L	15 min pre to immediately after the match	Absolute differences (*t*-test, one-tailed)	[28]
Wrestling matches	15	Δ T: W>L; C: W > L	10 min pre to 10 min post	Percent changes Duncan's test	[18]
Wrestling competition	15	Tsal: n.s.; Csal: n.s.	Resting day, two-day competition (8:30, 11:30, 15, 17:30, 19:30) and 8 days after (17:30)	Wilcoxon test	[26]
Judo combat	14	Δ T: n.s.; Δ C: n.s.	10 min pre to 45 min post	Percent changes (*t*-test, two-tailed)	[19]
Judo combat	17	Δ T: n.s.; Δ C: n.s.	10 min pre to 45 min post	Percent changes (*t*-test, two-tailed)	[20]
Judo combat	28	T and PRL: n.s., C: W> L	10 min pre to 10 min post	ANOVAs of repeated measures	[23]
Judo competition	12	Tsal: n.s.; Csal: n.s.	2 pre- (60 and 20 min) and 3 post-samples (10, 30 and 45 min)	ANCOVAs	[24]
Regional Judo Championship	18	Tsal: W<L; Csal: n.s	3 fixed time points: 8:00, 12:00 and 17:00 h (Competition between 12:00 and 17:00)	ANOVAs of repeated measures	[25]
Chess: regional tournament	11	Tsal: ↑ W > ↑ L	8 samples along 3 days (differences appeared the following morning)	ANOVAs of repeated measures, (*t*-test)	[27]
City tournament	8	Tsal: W > L after the sixth, seventh and final games	3 samples two days a week for 9 weeks	ANOVAs of repeated measures, (*t*-test)	
National basketball league	16	Tsal: n.s.; Csal: n.s.	45 min pre to 15 min post	ANOVAs of repeated measures	[30]

T, levels of testosterone in serum or plasma (if in saliva, Csal); C, levels of cortisol; PRL, levels of prolactin; ΔT, response or changes in testosterone; ΔC, response or changes in cortisol; W, winners; L, losers.

clearly in other contexts of human activity, in which there is, however, an important degree of competitiveness. Based on these factors, the majority of research on this topic has been carried out in the sports context (Table 1).

3. Sports competitions in men

In an initial study, Mazur and Lamb [17] concluded that the pattern in T changes was different depending on the outcome, with winners showing significant T increases and losers displaying obvious decreases, when values obtained 1 to 2 h after tennis matches with a clear victory were compared (binomial test). Some time later, it was reported that subjects winning a wrestling match showed significantly greater increases than losers when percent changes between T levels seen 10 min before and 10 min after the match were compared; winners also showed significantly greater levels of C than losers [18].

When we compared T and C changes (percent changes) experienced by young male judo competitors in response to a judo combat, non-significant differences were found; blood samples were taken 10 and 45 min after the fight. However, when we grouped subjects depending on whether they belonged to the Autonomic Team (higher rank) or not, significant differences in the T response appeared [19]. In addition, we found a significant correlation between T response and an index of 'previous victories' obtained from the sports records. Based on these results, our interpretation was that the T response was more related to characteristics of status (rank, previous experience, etc) than to the outcome obtained in a sole competition. In a second study, we attempted to verify this possibility by confronting members of the Spanish National Team of Judo with others from the Autonomic Team (of a lesser category) in a prepared *ad hoc* competition [20]. Again, non-differences appeared among winners and losers, with higher differences (although non statistically significant) between members of both teams differing in sports rank. The fact that the members of the Autonomic Team who ended up winning displayed the highest decreases in T, contrary to what was expected, suggests that the physical effort made during the combat could be the cause of these reductions, which compensated for the increases associated with the victory. When only members of the National Team were taken into account, winners showed T increases and losers T decreases, although not statistically different. The sports category again seemed to be an important, moderating variable. We also considered that this variable involved more than just the experience of 'success', because a different degree of physical fitness and training was involved. There is a vast amount of literature in Sports Medicine that suggests that numerous physiological responses, hormonal responses among them, are different depending on the physical fitness of the individual. Later studies have allowed us to confirm this point [21,22]. No significant differences were found in C responses in either study [19,20].

Sports competitions involve an important degree of physical effort capable of affecting T and C responses, but the influence of this effort was not controlled in these earlier studies. Additionally, this influence is moderated by the physical fitness of each individual, thus introducing new confounding sources of variability. Employing physiological (lactic acid, HR) and subjective scales (Vigor and Fatigue scales of Profile of Mood States, POMS) as effort indicators, we aimed to control the contribution of this factor in the hormonal responses to outcome [23]. In this study, we compared the effects of a judo combat with those displayed in situations involving non-effort and non-competitive effort. To this end, serum T and C were measured in judo fighters with similar levels of physical fitness who participated in three sessions (control, judo fight, and ergometry). Our results showed a hormonal response to competition, which was especially characterized by an anticipatory rise in T and C. Significantly higher C but not T levels were found in winners, compared to losers, throughout the entire competition, with both groups making a similar physical effort. However, winners experienced a very homogeneous T response with increases in 13 out of 14 judo competitors, whereas losers showed a greater variability, including increases and decreases. Furthermore, similar hormonal changes in the fight and in a non-competitive effort with the same caloric cost were found. We introduced some tests to evaluate the subjects' cognitive and affective assessment of the situation. Before the combat, winners perceived themselves as having more ability to win (self-efficacy) than losers, although there were no significant differences in motivation to win. After the combat, the winners showed a higher satisfaction with their performance and with the outcome. We found significant, positive correlations among T changes and motivation to win in the entire sample, as well as between C response and self-efficacy in losers, suggesting that those subjects who perceived themselves as capable of winning, but lost, experienced more increases of C. We concluded that in humans, hormonal response to competition is not a direct consequence of winning and losing, but is instead mediated by complex psychological processes.

The availability of salivary analyses of hormonal concentrations facilitated the use of authentic competitions, as well as making it possible to obtain a greater number of samples in order to get a more complete view of the hormonal response. Therefore, we studied a real judo competition between clubs within a championship, controlling for physical effort developed throughout several combats of each judo fighter, by means of levels of lactic acid and Borg RPE scale [24]. Results showed non-significant differences, with regard to the outcome, in hormones, physical exertion, mood and causal attribution. Only satisfaction with the outcome was significant,

obviously with higher scores in winners. Interestingly, T response was positively associated with self-appraisal of performance and attribution of outcome to personal effort. In this study, C response showed a very consistent relationship with negative mood (POMS total score). These findings support the role of cognitive and emotional factors, rather than the objective characteristics of the situation (outcome), in explaining the competition-induced hormonal responses. Effects of outcome on T and C response in a Regional Judo Championship have also been investigated [25], finding a lack of effects on C and higher T levels in losers. Each judo competitor participated in a different number of fights (one to four), and physical effort made was not controlled or measured in this study. In addition, an anticipatory response of C, but not of T, was found. Although non-significant correlations were found among hormonal and psychological variables, losers experienced significantly more state and cognitive anxiety just before the competition. Furthermore, they scored significantly higher on some dimensions of coping style (self-blame; avoidance; social support) and lower on others (positive re-evaluation), in responses obtained after the last fight. Significant effects of outcome were not found in a wrestling competition either [26].

Other studies controlled for physical effort by employing sports competitions in which it is not necessary, as in the case of chess. Significant differences, depending on the outcome, were found in a regional tournament, but they were not replicated in another tournament of less relevance. Time intervals employed were of more than one day and, even, in the second case, several weeks [27]. A follow-up of various months had been previously employed by these authors when they took salivary samples of six tennis players, one day before, 15 min before, immediately after and 1 or 2 days after several tennis matches; significant differences in T levels of winners and losers were reported [28]. Several methodological aspects of this research were rigorously criticized by Archer [29].

4. Team sports competitions: confrontation between groups

Competition in humans implies, on numerous occasions, the coordinated and cooperative work of members of a social group to cope with a conflict involving another social group for a common goal. Team sports are considered a good model for certain organizational formats. Among them, basketball is a model for the voluntary cooperation among the different parts [16], and although the outcome is based on team work, an individual contribution index can be obtained. This strategy, which had not been previously employed in this research area, allowed us to separate outcome from performance, in order to better analyse the effects of each.

We studied the effects of outcome on T and C responses in two professional basketball teams in a real match with a high level of competitiveness (Spanish National Basketball (EBA) League). The purpose was to explore the relationships of these responses to different psychological variables such as mood, performance appraisal, causal attribution, and individual contribution to the outcome. Results did not show statistically significant different T and C responses depending on the outcome. Negative mood was significantly enhanced, especially in the losers, while winners showed a better appraisal of team performance and a greater internal attribution. T response did not show a significant relationship with mood changes, but it correlated positively with the 'score/time playing' ratio, an indicator of individual participation in the outcome. Furthermore, T response correlated negatively with external attribution in winners and positively in losers. These results confirm the idea that in a real, highly competitive situation, T changes are not directly related to the outcome, but rather to the contribution the individual makes to it and to the causes he attributes to it [30].

In order to delve more deeply into the role of these factors involved in T responses to competition, we studied these relationships after a successful competition. Salivary T levels and mood of members of two basketball teams that both emerged as winners in two authentic matches were compared [31]. The influence of several factors (sports ranking, time playing, circadian rhythms, home court, personal contribution, fatigue, sexual activity, and satisfaction), which could modify T differently in both matches, was controlled. Mean T concentrations increased in Team 1, but not in Team 2, who attributed their victory more to luck and showed notably decreased vigor than did Team 1. Post-match T levels were only significantly, negatively related to external attribution. These results support the idea that causal attribution of the outcome contributes to the variance of the T responses to real confrontations where the outcome is highly dependent on personal merit. They indicate that factors apart from the objective outcome contribute to the androgenic response; the greatest T increases are observed after a clear victory with minor external attribution. Both teams were located at the top of the ranking and played in their home court, but against opponents situated at the top (Team 2) and at the bottom (Team 1) on the current ranking. This latter team was the 'favorite', and it apparently had more expectations of winning and an easier victory, as actually occurred. In other words, it was more dominant than its opponent. The opposite was true for Team 2, who competed with a rival of a higher level. Although this team became the winner, they experienced decreases in vigor and attributed the outcome more to luck than to merit. Recently, higher salivary T levels before games played at 'home' than before games played 'away' were reported in professional male soccer players, emphasizing the role of territoriality seen in other species [32].

5. Laboratory competitions

This topic has also been studied in laboratory settings. In one study, significantly higher salivary T levels in winners than in losers were reported during a time reaction task whose outcome was manipulated by the experimenter. Depression was higher in losers when the victory was clear, whereas anxiety was not sensitive to the outcome [33]. Again these authors [34] found greater T increases and more positive mood in winners than in losers when involved in a task entirely controlled by chance (coin tossing). They emphasized the reinforcing power of mood, although they stressed the existence of other elements, and concluded that the perception of winning or losing, regardless of actual performance or merit, influenced T levels differently. In this context, it is worth noting that T increases or decreases in fans, depending on the outcome of their team, have been reported [35]. Neither personal contribution nor merit could explain these responses.

These studies contrast with the lack of significant differences between lottery winners and losers previously reported [17]. Furthermore, these authors emphasized that mood mediated the T response to outcome obtained in tennis matches based on the fact that three of the four winners who said they felt well showed increases, while the fourth man, who experienced confusion, did not display an increase [17]. In a posterior study, they confirmed that T variations among samples obtained 15 min before and immediately after the matches correlated with the positive mood estimated by just one question, which, according to the authors, supported the importance of mood for the endocrine changes to competition [28]. More recently, the lack of significantly different T and C responses to a video game contest in winners and losers has been explained as being due to the absence of mood changes [36].

Findings from animal research are based on the contribution or merit of individuals, who win or improve their status, with individual effort being important in achieving the victory. In these types of competitions, outcome depends on the actions of the individual, it influences its future behavior, and it has consequences which can vary in importance for the animal. This situation contrasts with the aforementioned results described concerning victories associated with chance or manipulated by the experimenters. The competitiveness involved in the laboratory tasks is very different from that originating in sports competitions and other everyday competitive situations, where the outcome has important consequences for the status. However, studies focusing on real situations have an important limitation, due to the low number of subjects. Furthermore, the impossibility of replicating the conditions of each situation prevents the aggregation of cases. A good strategy is the complementary use of both types of situations. The higher possibility of controlling variables in the laboratory improves the examination of hypotheses appearing in the context of real competitions. This strategy has been employed in our latest study (data not published), in which we aimed to compare T and C responses in two tasks differing in the perception of control of outcome by the subject. In one task, the individuals thought the outcome depended on their effort (internal attribution), whereas in the second task they thought the outcome depended on chance (external attribution). To obtain a more complete picture of psychobiological response to the situation, we also introduced cardiovascular measures, concretely heart rate (HR) and blood pressure (BP), during the three phases (pre, task and recovery periods). Significant differences depending on outcome were found in HR and BP, as well as in C after the task (5 min for cardiovascular measures and 40 min for C). However, the type of task (internal vs external control) also affected the T and cardiovascular responses during the task. These responses were higher when subjects perceived that the outcome was under their control; in addition, a decrease in positive mood was observed in this task. In a previous study, we assessed the effect of a competitive role-play game on HR and BP in a sample of university students; the influence of anxiety and attributions of the outcome were also explored. Only winners showed a significant rise in HR during the competition, followed by a decrease during the post-task phase, in addition to more internal attributions. On the contrary, the mean HR for losers during the competition was lower compared with their baseline values. No differences depending on the outcome were found in BP. The cardiovascular response, as well as the subjective interpretation of the outcome, suggested a more active strategy employed by winners as opposed to a more passive strategy used by losers [37]. In spite of the fact that competition has been conceptualized as acute stress, there is very scant information about the cardiovascular impact of competition. Increases in BP and HR, and a marked shortening of the pre-ejection period of the heart (a sensitive index of beta-adrenergic influence on the heart), have been related to competition and competitiveness [38,39].

6. Competitive stress in women

Just as animal models of social stress are based almost exclusively on males, studies on the effects of social stress and on aggressive, dominant or competitive behavior in humans have also been carried out mostly in men. However, women react to stressors, especially social stressors, in a different way from men [40–42]. The importance of considering gender differences in stress response, and the vulnerability to its noxious effects in different species, is increasingly emphasized, as is the need to develop specific models [43,44].

Using different competitive situations, the effects of outcome on T and C response were not found in women. In a previously mentioned study employing a video-game contest, neither anticipatory increases nor significant responses were reported [36]. In sports competitions, non-significant

differences depending on winning or losing have been found in rugby teams [45] and soccer players [46]. Recently, positive relationships between T and dominance [47], and with competitive aggression [48], have been reported. The importance of competitiveness for women, and the role of different hormones, must be examined in the light of evolutionary approaches [49]. The possibility of different strategies for coping with stressors, tend and befriend vs fight or flight, is currently being debated [50–52].

7. Anticipatory hormonal responses

An important point to underline is the anticipatory response to competition found in T and C. A clear response was found in a judo combat, comparing it with another session of equivalent physical effort but without competitiveness [23]. This has been confirmed by comparing C concentrations before the combat with mean C obtained in eight resting sessions carried out at the same time of day throughout an entire sports season. This anticipatory response did not appear in the whole group of judo players; however, an individualized analysis showed different patterns in the pre-competitive T behavior. The T increase, greater than 15% of baseline values in all the T-responders, was accompanied by a greater motivation to win and higher C levels just before the competition. Furthermore, this group also obtained a better outcome [53]. An elevated level of T previous to competitions was also reported in other studies [27,28,36]. When previous levels of T were correlated with behaviours displayed during a judo combat, significant, positive correlations with number of threats, attacks and fights were found [54].

Interestingly, another recent paper has examined the pre-competitive values of T in soccer players in order to determine their role in the 'home advantage', which is recognised in virtually every team game [32]. T concentrations measured before home games were significantly higher than those obtained before 'away' games and neutral training sessions. However, the self-report ratings of dominance and mood did not relate to T, venue or rivalry. Finally, some differences were detected for player position: offensive players (strikers) tended to have higher levels across the different venues, while the goalkeepers had the lowest in training and the highest against the extreme rival. Previously, we reported the importance of court position in basketball players; this factor showed a significant effect on T changes, with increases only found in forwards [30]. In both cases, players on sports teams with a more offensive position showed more T response.

8. Intervening variables of the T and C response to competition

In summary, results on this topic do not reflect a clear, unanimous panorama, contrary to the conclusions drawn in some reviews, in which the first results published are cited, confirming findings obtained in other species e.g. [12,15]. This inconsistency has given rise to several proposals about different variables that could intervene (moderating or mediating) between hormones and behavior.

Steptoe [55] classified the relevant factors that influence the psychophysiological response to stress into three groups: characteristics of stressor, psychological and personality characteristics (psychosocial resources) and biological and constitutional factors of the individual. In the previous review of the literature on this subject, I have named variables from these three groups and outlined the support provided in each case. Among the characteristics of a competitive situation, we find the duration and intensity of the physical effort developed. We could not confirm differences between winners and losers (employing lactic acid, HR and subjective data as indicators of physical effort), although we could not find differences in the hormonal response either. The role of physical effort continues to be cited as a possible cause of the lack of differences [46]. Another situational variable is the importance of the competition for status or ranking, which matches the hypothesis of challenge [56]. However, this importance may vary depending on the personal appraisal of the individual, which also implies a different involvement. The role of 'territoriality' has recently been confirmed in men (home or away games). However, the role of ranking/rivalry of the opponent seems to have complex effects related to whether the outcome is obtained by a clear advantage or not. An extremely complicated, although basic, variable is whether the outcome is under personal control or not (e.g. chance). Its theoretical importance is not entirely supported by the findings. The associations between T and personal contribution to the outcome, as well as with the position/role in the game (more or less offensive) [30,32], seem to confirm their role in animal competitions. However, other data obtained in luck-tasks is disconcerting.

Among personal resources and personal characteristics, better mood experienced with victory was emphasized, based on some initial studies. In others, however, dissociation between T response and mood has been found, T being associated with motivation to win. Mean levels and changes in T were positively associated with items linked with involvement and anger displayed during contests, as assessed by the coaches in two different studies [57,58]. It is worth noting that involvement in the task, competitiveness and goal/power motivation are included among type A pattern main characteristics. Some studies have emphasized the importance of subjects' enduring characteristics for the T response, such as type A [59] and personalized power motivation [60–62]. However, personality traits have not yet been sufficiently studied in this context. Some recent data indicate relationships between pre-competitive and changes in T values with ratings of social importance, competition-related abilities and bonding among team players (men and women) [63,64]. Importance of coping

strategies and styles have also been suggested [25] and emphasized [53]. These strategies depend on their perceived control, the causal attribution made by the subjects, their expectations of success, self-efficacy, etc. Finally, among biological factors, the relevance of physical fitness, body mass, diet or fasting, among others, are increasingly recognised. Age has not yet been studied, and gender has only begun to be considered in the last few years.

9. Concluding comments

From the studies reviewed, we obtain fragmentary information about a global psychophysiological response to a social stressor, which is, of course, affected by a great number of variables. Previous information about the hormonal response to outcome may be, in my opinion, better integrated, if we consider it as a part of the coping response to competition (Fig. 2). Winning or losing does not increase or decrease T concentrations. Instead, victory will be more likely if the subject appraises the competition in such a way that his/her coping pattern is characterized by a sympathetic (SNS) activation and a subjective experience of challenge (active or proactive coping response). If a passive coping response prevails, the possibilities of defeat will increase.

In addition to the predominance of HPA and SNS axes in certain dimensions of stress response, neuroendocrine activity during an exposition to stress includes other systems. T has been traditionally associated with competitiveness, power-motivation and dominance [65], but it has also been included within an active coping strategy [66–68]. In the previously mentioned study employing two competitive laboratory tasks (effort vs chance) in young men, a factorial analysis showed two main factors. The first included HR, BP and T changes, whereas the second grouped mood and C changes (data not published yet). These factors match the two coping styles described in the literature (active vs passive, proactive vs reactive, effort vs distress).

The important role of psychological factors in understanding the neuroendocrine response to stress has been emphasized by important researchers [69–71]. In this context, a very influential conceptualisation has been that formulated by Lazarus and Folkman. These authors differentiate primary and secondary appraisal [72], which are equivalent to stimulus expectation and expectation of outcome in the model by Ursin [73]. The prevailing coping strategy depends on the primary appraisal, which involves the situation (importance for the subject, relevance for status), and the secondary appraisal. In this latter case, the main point is whether or not there is a fit between the demands of the situation and the resources of the individual to cope and control it. Aspects such as locus of control, stability and controllability play an important role; these are the dimensions of the causal attribution [74]. Conscious or unconscious thoughts of the individual will ultimately determine the coping behaviour. If the individual 'appraises' the situation as important for him/her and dependent on him/her, and he/she has resources to control it, the probabilities of employing an active strategy increase. This coping response includes increases in T (especially in an aggressive/competitive situation) and SNS activation.

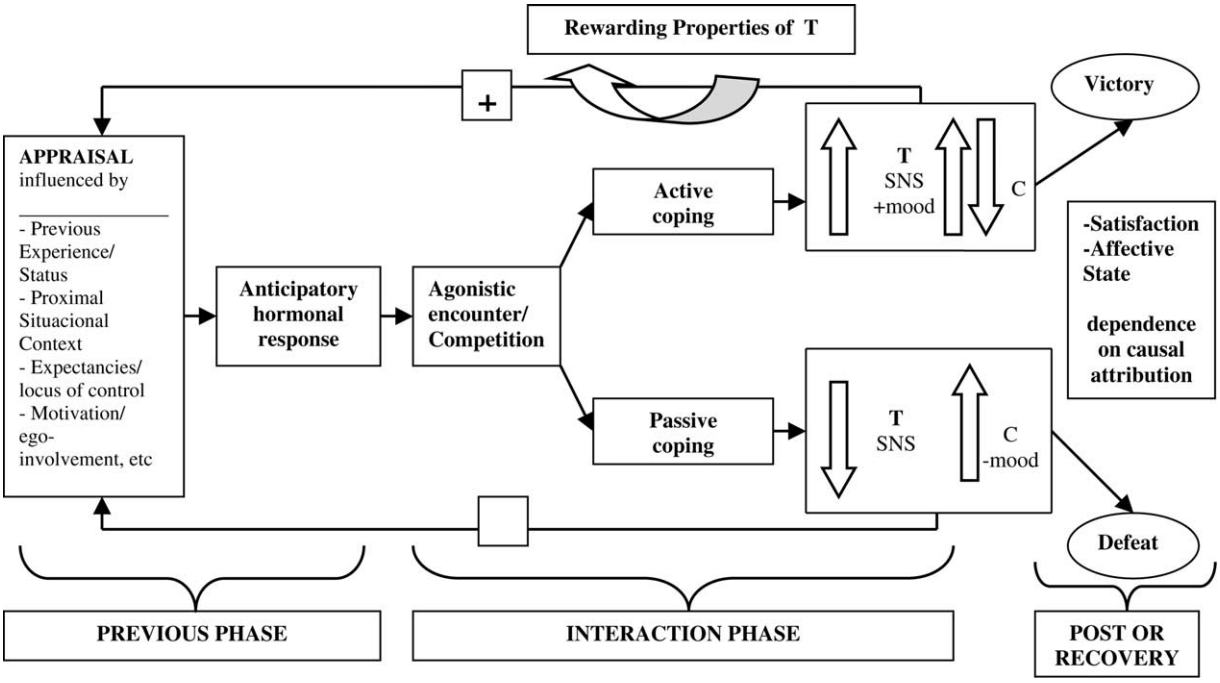

Fig. 2. A tentative model of hormonal response to competition (see text).

Mood might be positive in a self-confident person with feelings of self-efficacy who interprets his/her anxiety as facilitating within an interpretation of competition as a challenge [75–77]. In the majority of competitions, an active pattern of responses would increase the probability of obtaining the victory. On the contrary, a passive pattern, characterized by negative mood and C increases together with an insufficient T and SNS activation, would lead to a greater probability of defeat. Status, previous experience, proximal context, expectations of outcome, among others, affect the activation of one response pattern or another. With regard to C levels, an anticipatory increase would imply an adaptive response, especially if a high energetic cost is foreseeable in the near future [78], but it would be accompanied by a posterior reduction. Elevated levels later, especially long after the end of the competition, seem to be related to more distress and an inadequate interruption of the response.

Differences in the response patterns to stressors in dominant and submissive animals are well documented [67]. It is worth noting that dominant males showed T increases, compared with T decreases in subordinate male baboons, in response to a stressor (anaesthesia injection), which was related to SNS response [79]. Maybe coping styles shown by individuals who perceive control and expectations of success are comparable to those displayed by dominant males, facilitating a T increase also in men. Another important point concerns the possibilities of T to facilitate the upcoming competitive behaviour. In the last few years, rewarding properties of T have been studied. In mice, we confirmed these properties in young males without agonistic experience [80], with the experience of a sole victory against an anosmic, non-aggressive opponent [81] and, recently, with successive experiences of victory, whereas the repeatedly defeated animals did not present this effect (data not published yet). These data support a role of T in the subsequent competitive behaviour.

In conclusion, winning or losing does not increase or decrease T concentrations. Instead, in order to understand the hormonal response to competition in humans, we must obtain a more complete image of the process and pay special attention to the coping strategies: Table 2.

Table 2
Some moderating factors of the hormonal response to competition

Factors	Measured by means of:	References
Sports status:	Index of previous victories from sports recordings	[19,20]
	Sports rankings	[31]
Physical fitness	$V0_{2\ max}$; W_{max}; Anaerobic $power_{max}$; % Body fat; BMI; Strength	[23,24,30,31]
Physical effort/ exertion:	Lactic acid Heart rate Vigor and Fatigue scales of POMS Borg RPE scale Duration of competition	[23,24,30,31]
Mood	POMS	[24,30,31]
	PANAS, MAACL	[33,34]
	Direct, open questions (e.g. 'How do you feel right now?')	[17,28,36]
Individual contribution to outcome	'Score/time playing' ratio	[30,31]
Appraisal/satisfaction of performance/outcome motivation to win and Self-efficacy	Items answered according to 5-point Likert-type scale (e.g. 'How much do you feel capable of beating your opponent?')	[23,24,28,30,31]
Causal attribution	Internal attribution (personal effort, physical and technical abilities) external attribution (mistakes made by adversaries, luck, decisions of referees)	[24,30,31,34]
Anxiety	STAI, CSAI-2	[25]
Type A	Bortner test	[25]
Coping styles	'Ways of coping checklist'	[25]
Territory	Games played at 'home' or 'away'	[32]
Court position	Position of each player	[30,32]
Others	BMI	[23,24,30,31]

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