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Genetic and non-genetic determinants of aggression in combat sports

Abstract: Human aggression/impulsivity-related traits are influenced by complex genetic and non-genetic factors. The aggression/anxiety relationship is controlled by highly conserved brain regions including the amygdala, hypothalamus and periaqueductal gray of the midbrain, which is responsible for neural circuits triggering defensive, aggressive, or avoidant behavioral models. The social behavior network consists of the medial amygdala, medial hypothalamus and periaqueductal gray, and it positively modulates reactive aggression. An important role in the incidence of aggressive behavior is played by secreted factors such as testosterone, glucocorticoids, pheromones, as well as by expression of genes such as neuroligin-2, monoamine oxidase A, serotonin transporters, *etc.* The authors deliberate whether aggression in sport is advantageous (or even indispensable), or to what extent it can hamper attainment of sport success. Methods of reducing and inhibiting expression of aggression in athletes are indicated.

Keywords: combat sports, aggression, association, impulsivity, polymorphism, genes

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1 Introduction

A combat sport is a contact sport involving one-on-one combat. Particular rules of individual combat sports determine the winner of competitions, e.g., by scoring more points than the opponent or by disabling the opponent. Eastern martial arts, wrestling, boxing, fencing, or mixed martial arts are some examples of combat sports. Combat sports athletes are required to possess well-developed technical and endurance skills [1-3], optimal fitness, speed, strength and flexibility, and a tendency to avoid injuries [4], and benefit from most recent advancements in biomechanics [5]. Apart from these requirements, combat sports athletes are also expected to display optimal levels of anxiety [6], motivation and self-confidence [7]. The question remains whether they also require aggression.

The term aggression comes from Latin *aggressio*, meaning attack. The first use of the term can be traced back to 1611 in the sense of "provoked attack". Aggression, in its psychological manifestation as "hostile or destructive behaviour", appeared first in English translations of Alfred Adler's (1908) and Sigmund Freud's works (1912).

Aggression can be defined in a variety of ways, depending on whether it is treated as physical or verbal. In the narrow sense, aggression is a deliberate action referring to a range of behaviors that can result in both physical and psychological harm to oneself, others or surrounding objects; or, it is an action aimed at attaining relative social dominance [8]. Aggression is traditionally divided into five categories: defensive, offensive, maternal, play fighting, and predatory [9,10]. The first four types should be described as social aggression because they involve an interaction with a nonspecific animal. Predatory aggression is considered to be a controlled, planned and goal-oriented type of aggression, and predatory aggression personalities (*i.e.*, psychopaths or sociopaths) consider themselves superior to others.

Some authors divide aggression into two types. The first one results from a lack of emotionality, during which the behavior of individuals with reduced emotional sensitivity appears premeditated and deliberate. These personality types do not usually feel a sense of regret after performing an act of violence. The other type is "reactive aggression," characterized by an excess of emotional sensitivity, and triggered by negative emotions, difficult life experiences, anxiety, and anger [11]. This behavior

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appears as a result of an exaggerated perception of threat and response to it, together with an inability to control the resultant enhanced emotional state [12]. Although the overall objective of aggression is to assert physical or territorial dominance, a number of different specific forms of aggression can be noted, such as expressing anger or hostility, competing with others, intimidating or threatening, responding to fear, reacting to pain, achieving a goal, or expressing possessiveness [13,14].

2 Non-Human Animals

Ethologists often use the term 'agonistic behavior' when referring to such stereotypical signals as baring teeth, snarling, showing claws, bristling up, producing certain facial expressions or vocalizations, pushing with one's body, biting, or nipping. What is interesting, however, is the fact that the majority of such animal behaviors are means of dialogue aimed at ensuring a hierarchy in a herd or group. They are very rarely aimed at causing physical harm. Agonistic behaviors confer biological advantages such as securing territory, food, water, protecting offspring, and securing mating opportunities. In the animal world, communication is mainly based on indicating one's strength vocally or through body language. Such behaviors are usually explained with the use of hawk-dove game theory or sequential assessment and energetic war of attrition.

3 Humans and the gender factor

Clearly, aggressive behaviors in sport is becoming more frequent and intensive, particularly in such team games as American football, soccer, handball and ice hockey. Are aggressive behaviors becoming more common in combat sports? In competitive sports, especially in combat sports, some forms of aggression may be sanctioned [15]. The question as to whether they are advisable and beneficial to athletes will be discussed further on.

Are there any differences between aggressive behaviors in men and women [16]? In fact, there is no precise answer to the question as to why these behaviors differ to such an extent in males and females [17]. To put it simply, aggression in women is more indirect and less physically dangerous. In contrast, men more frequently resort to direct aggression than women. What is interesting is that the intersex differences can be only observed after the second year of life [18]. This is explained by the fact that girls develop language skills more quickly than boys, and it is easier for them to express their needs verbally. It should also be mentioned that according to US data, men tend to commit murders ten times more frequently than women [19]. In other countries, e.g. New Zealand, women are involved in violent crimes 2-3-fold less often than men [20]. In studies on domestic, wild and laboratory animals, a strong association between testosterone levels and aggression intensity has been found [21]

In sport, on the other hand, differences in aggression between the two sexes appear to be insignificant, both in combat sports and in other sports based on direct competition (e.g. team games). The differences can be seen in a higher scale of indirect hostility in women, and in a higher scale of assault in men [22].

For some coaches, one of the most important elements of mental preparation for athletes is aggression enhancement. This is particularly visible in contact sports such as American football, rugby, basketball, and handball. Undoubtedly, locker room pep talks delivered by coaches before important matches include such expressions as "destroy the opponent", "level them with the ground", and "knock them out". A spectacular example is the ritual in New Zealand's All Blacks' Haka dance performed before rugby matches. One of the most expressive Haka gestures is made with a thumb drawn down the throat and poking out the tongue, interpreted as a gesture for throat slitting. Female players of competitive sports do not go that far, and are positioned much lower on the assault scale.

It can also be noted that men with higher social skills demonstrate a lower rate of aggressive behavior than men with lower social skills. In females, higher aggression levels seem to be associated with higher rates of stress. Apart from biological factors, physical factors also contribute to aggression [23]. There are some interesting theories concerning the incidence of aggression in men, e.g. sociobiological theories of rape and theories regarding the Cinderella effect [24]).

"From the evolutionary point of view, aggression in humans could be considered an evolutionary positive trait that provides success in competition. However, from the social point of view, aggressive behavior hampers or even prevents an opportunity for social consolidation" [25]. Considering both the positive and negative consequences of aggression, it should be stated that human aggression must be regarded as an evolutionarily significant and genetically modulated trait [26].

4 Brain pathways

As shown in many studies on animals such as cats, rats and monkeys, the hypothalamus and periaqueductal gray of the midbrain are critical areas for controlling the expression of both behavioral and autonomic components of aggression (Fig.1). As observed by Hermans *et al.* [27], when the serotonin and vasopressin receptors in the hypothalamus are subjected to electrical stimulation, such stimuli induce aggressive behaviors [28]. Studies on animals such as Rhesus monkeys also show that the amygdalae are involved in aggression control [29]. Lesions both in the amygdalae and the hippocampus may lead to a lowering of the level of social dominance [29, 30]. Considering the issue of aggression at the level of neurotransmitters in the brain, it should be noted that a serotonin deficit might be a potential cause of aggression. Other potential compounds involved in aggressive behaviors include norepinephrine, dopamine, GABA [31] or catechol-O-methyltransferase [32].

While defensive rage and predatory attacks are elicited by electrical stimulation of many brain regions in the cat (Fig. 2), stimulation of a given brain region elicits only one of the two, but never both [33]. Thus, these two classes of behavior are mediated by different neural circuits. Other forms of aggression, such as offensive and maternal, may involve more similar neural circuitry. When male and female rodents are placed in situations that would elicit offensive aggression and maternal aggression, respectively, Fos-like immunoreactive (Fos-ir) neurons are found in similar brain regions in both sexes [34-38].

Although offensive aggression and maternal aggression have been traditionally difficult to discern in terms of gross neural circuitry, they appear to be biochemically distinguishable. Offensive aggression is generally enhanced by the presence of circulating testosterone, whereas maternal aggression is not or may be even inhibited by it [39]. Treatment with drugs that alter serotonin reliably affects offensive aggression and predatory behavior [40- 42]; however other drugs, e.g. fluprazine, affect offensive aggression but not predatory behavior [43,44]. Thus, although the brain regions involved (e.g., the amygdala) may not distinguish between some forms of aggression, the types of cells involved within a brain region may differ (e.g., androgen receptor vs. estrogen receptor). Examination of different forms of aggression in Avpr1b –/– mice not only allows us to define further the role of the Avpr1b in aggression, but also to help explain how these various types of aggression can be differentially regulated.

Human aggression can be caused or alleviated by speech (Fig. 3). Is the central nervous system the primary source of aggressive behavior, or is it a more emotional process (e.g. a coach's pep talk before a game)? (see Al Pacino's monologue in "Any Given Sunday" dir. Oliver Stone). If we assume that a locker room pep talk does affect some brain regions, the process of this stimulation can be presented as follows:

Step 1. Intellectual stimulation – by coach's rhetorical devices.
Step 2. Emotional processes.
Step 3. Physical processes.

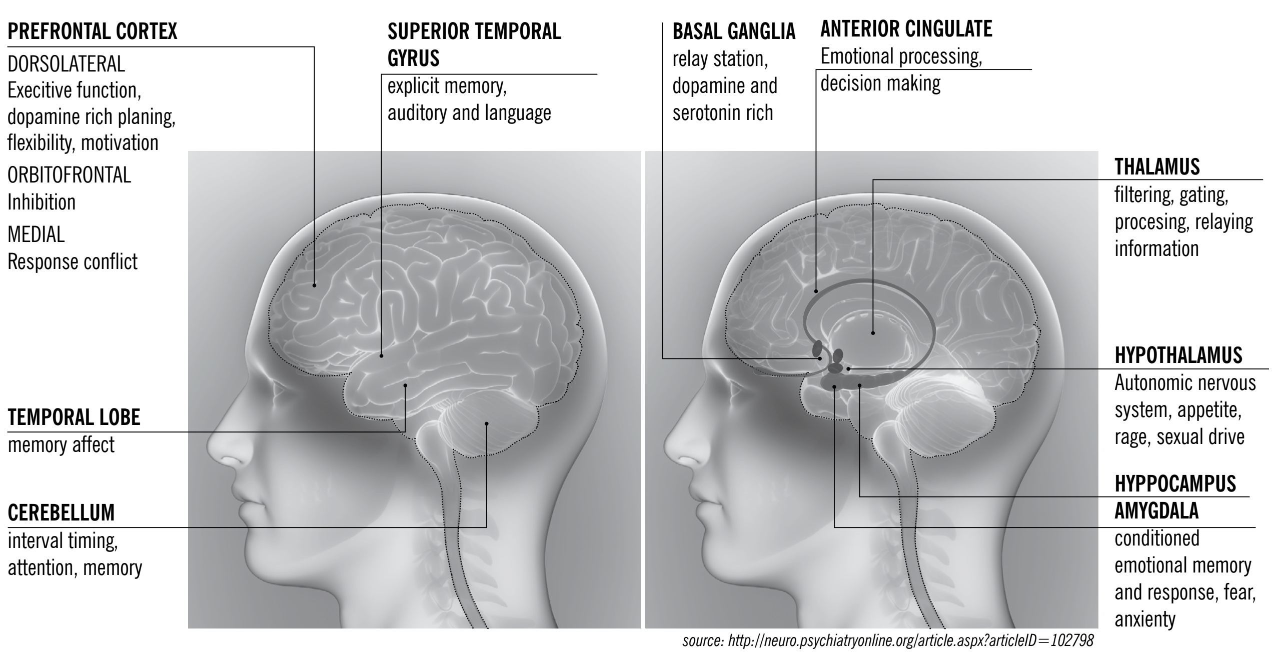

Figure 1: Brain regions involved in aggressive behavior and associated behaviour.

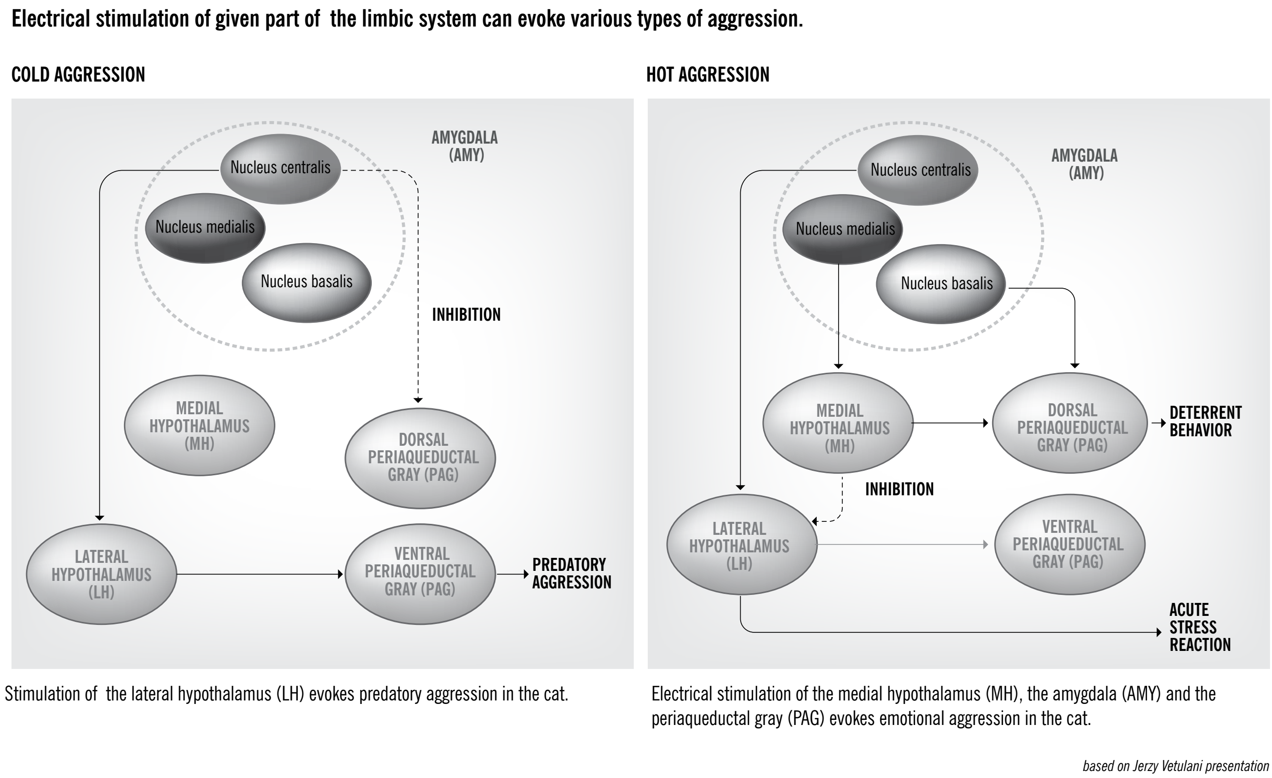

Figure 2: Cold and hot aggression.

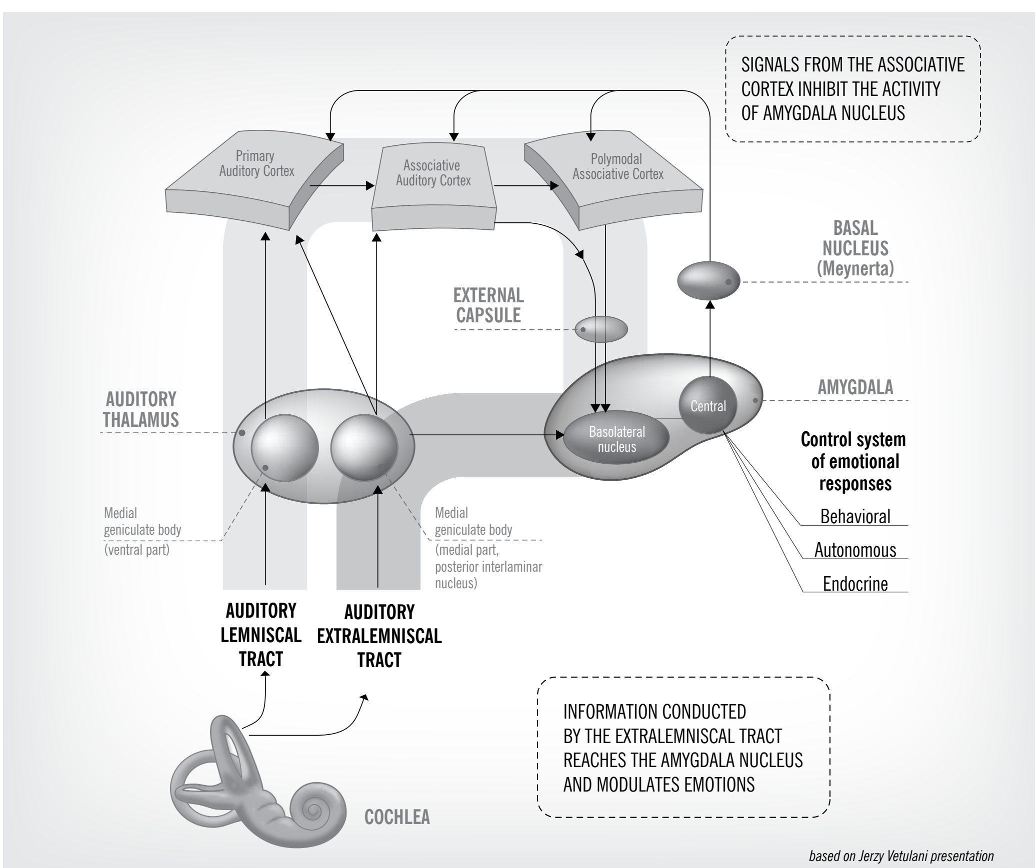

Figure 3: Human aggression can be caused or alleviated by speech.

Assuming the above process is valid, the emotional state can be considered as a projection of the intellectual stimulation results, while the physical state as a projection of emotional processes results. Aggressive behavior of the brainstem is controlled and inhibited by the upper parts of the nervous system (Fig.4). When the Italian soccer player Marco Materazzi verbally insulted Zinadine Zidane during the final of the 2006 FIFA World Cup (Step 1), he caused an emotional arousal in the French player (Step 2), which was then "projected" onto the physical state by Zidane's headbutting Materazzi (Step 3). According to Green, Green and Walters (1970), "Every change in the physical state is accompanied by an appropriate change in the mental emotional state, conscious or unconscious, and conversely every change in the mental emotional state, conscious or unconscious, is accompanied by an appropriate change" [7].

Incidentally, the intellectual process is relatively slower than the emotional process and body expression. Even without close scrutiny of the speed of mental processes, it can be asserted that if Zidane had at least reflected upon Materazzi's verbal insult without acting impulsively, he would have come to a realization that under the circumstances of the World Cup final game it would have been more prudent to seek an apology or retaliation outside the stadium, instead of headbutting an opposing player, being sent off and seriously weakening his team. The French team was then doomed to lose the final, after hundreds of hours of hard work by the players and the coaching staff.

5 Testosterone

Sex differences play a pivotal role in determining the intensity and frequency of aggression. As mentioned above, men are much more aggressive than women, and scientists have studied possible associations between levels of male hormones (particularly testosterone) and the magnitude of aggressive behavior. Testosterone is secreted in both males and females; however, in females it is excreted to a lesser extent. The question is whether these differences are related to the fact that women are less aggressive or that they manifest aggression in a different way.

A positive correlation between salivary testosterone levels and aggression in social situations was observed in boys (but not in girls) by Sanchez-Martin *et al.* [45]. In many investigations, the testosterone level positively correlated with aggressive behavior in men [46- 48]. To explain the

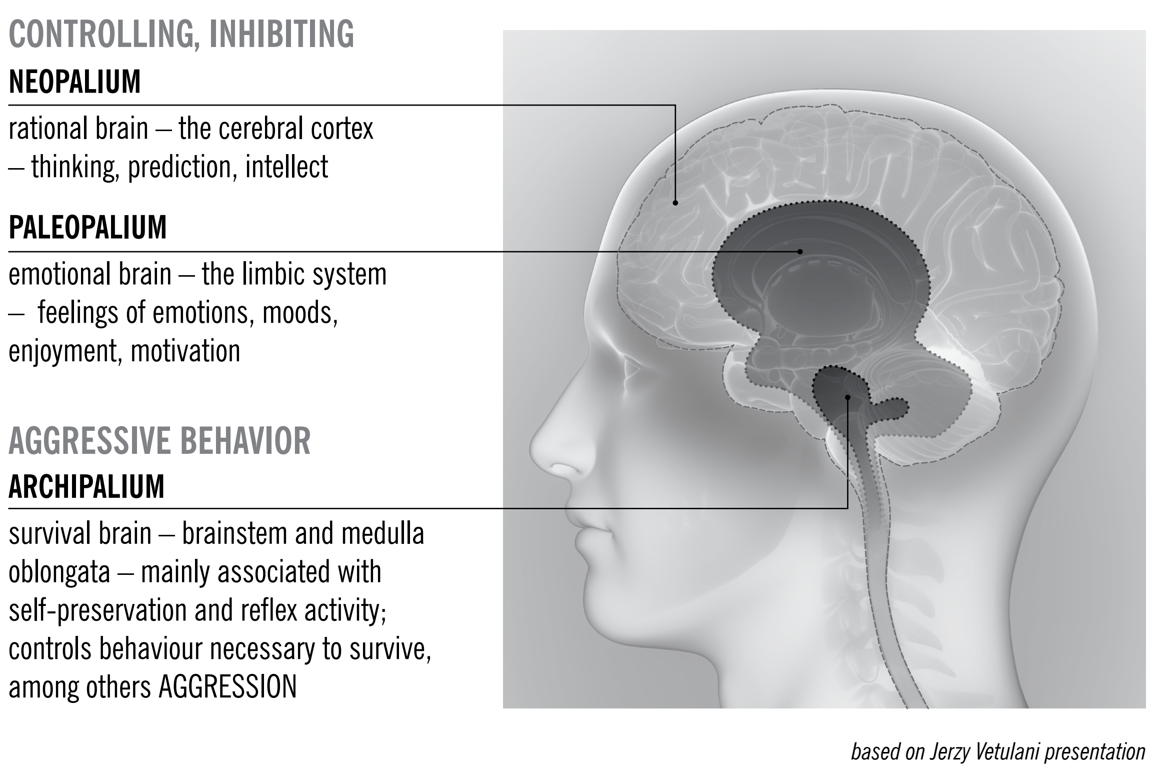

Figure 4: Aggressive behavior of the brainstem is controlled and inhibited by the upper parts of the nervous system.

increase in aggressiveness in adolescent and young adult men between the ages of 12 and 25, Wilson and Daly [49] proposed a hypothesis of "young male syndrome" based on the fact that the testosterone level increases significantly in early adolescence. This approach was an attempt to relate the so-called "challenge hypothesis" - originally concerning testosterone-aggression associations in some monogamous birds - to aggression in adolescent humans [50].

Testosterone is assumed to rise to moderate levels at puberty, and this assumption is supported by reproductive physiology and behavior. Puberty not only involves increasing androgen levels, but also enhanced competition between males resulting in aggression [51]. In contrast, when males take care of offspring, testosterone levels are shown to decrease.

The challenge hypothesis assumes a dynamic relationship between excretion of testosterone and aggression in mating circumstances. During mating fights, males are more determined and have a higher level of testosterone. This increases their level of aggression and reproduction chances Wingfield, *et al.* [52]. The presence of receptive and fertile females significantly increases the testosterone level in males, leading to aggressive interactions between the males [53]. Also, the conversion of testosterone to 17b-estradiol by aromatase, or to 5-alpha-dihydrotestosterone (DHT) by 5a-reductase appears significant in the context of emergence of aggressive behaviors. The expression of aromatase in the brain was shown to be exceptionally high in the regions involved in regulation of aggressive behavior, such as the amygdalae and the hypothalamus. The aggression level in murine models can be decreased by excluding aromatase knockout (ArKO) mice. On the other hand, the later injection of estradiol partially renews aggressive behaviors.

Testosterone may increase offensive aggression, but not maternal aggression, which may be even inhibited by it [54-58]. An imbalance in testosterone/serotonin and testosterone/cortisol ratios (e.g., increased testosterone levels and reduced cortisol levels) may be the reason for the increased propensity toward aggression due to reduced activation of the neural circuitry of impulse control and self-regulation [25].

Tests on animals show that the social behavior network consists of the medial amygdala, medial hypothalamus and periaqueductal gray (PAG), and that it positively modulates reactive aggression. An important role in this modulation is also played by other factors such as glucocorticoids [59] and pheromones [60] widely discussed in literature.

6 Genetics of aggression: in search of the "warrior gene"

Human aggression/impulsivity-related traits are influenced by complex genetic and non-genetic factors. The aggression/anxiety relationship is controlled by highly conserved brain regions including the amygdalae, which control neural circuits triggering defensive, aggressive or avoidant behavioral models [25]. In the late 1990s, our research team studied genetic determinants of aggression [61]. At that time, the search for candidate genes that could potentially influence aggressive behavior mostly focused on androgen receptors. Some years later, Aluja *et al.* [62] repeated the study on humans with respect to CAG repeats length polymorphism [62], and observed that androgen receptor CAG and GGN polymorphisms might influence impulsive-disinhibited personality traits. Other candidate genes included the SRY (sex-determining region Y) gene located on the Y chromosome, the STS (steroid sulfatase) gene [29,63], and the MAO-A gene [64]; however, some of those research results were not replicated or confirmed by other research teams.

The main problem in genetic research of aggression is the mapping of major genes involved aggression, which is most likely a sum of the effects of numerous genes of little impact, their mutual interactions as well as a genotype environment interaction. There is much evidence that aggressive behavior in humans is influenced by genes with heritability estimates of 44–72% [17,65-69].

The genetic background of aggressive behavior appears to be strongly influenced by the genetic variants of the serotoninergic system that affect serotonin levels in the CNS, biological effects of this transmitter, as well as the rate of serotonin production, release and utilization in synapses. Among polymorphic variants, functional differences in the monoamine oxidase A (MAOA) and serotonin transporter (5-HTT) may be of particular importance due to the relationship between these polymorphic variants and anatomical changes in the limbic system of aggressive individuals. Genetic polymorphism of 5-HTT seems to be correlated with the human adaptive ability to control emotions. This is particularly important during sports competitions accompanied by high emotional pressure. However, in their study of synchronized swimmers and non-athletes, Sysoeva *et al.* [70] did not reveal an interaction between sport and 5-HTT polymorphism. As well, the scores of Indirect Hostility were observed to be higher than levels of negativism and irritability in athletes with the SS genotype in comparison with athletes with the LS and LL genotypes [71].

Functional variants of NLGN2, MAOA, and 5-HTT are capable of mediating the influence of environmental factors on aggression-related traits. Below are examples of some interesting genes with a significant contribution to aggressive behavior. The discussion does not account for factors such as 5-hydroxytryptamine (5-HT), the effects of which have been widely described.

7 Neuroligin-2

Neuroligin2 (NLGN2) is a postsynaptic cell adhesion molecule predominantly expressed at inhibitory synapses. Kohl *et al.* [72] studied changes in the behavior of rats following the injection of a vector with NLGN2 to the hippocampus. The vector was prepared in such a way to ensure overexpression of the NLGN2 gene. Studies on the role of the hippocampus in aggressive and other social behaviors have been relatively new [73-76]. Changes of social behavior and altered inhibitory synaptic transmission, hence modification of the excitation/inhibition (E/I) balance, have been observed. Until recently, it has not been clear how a shift in the balance of the E/I ratio impacts on altered aggressive behavior. When rats were injected with the NLGN2-overexpressing virus, they attacked the intruder less often compared to animals injected with the empty construct. During the tests, three aggression-related types of behavior were registered: keeping down, lateral threat and offensive upright. In the case of keeping down – a strong parameter for offensive behavior - they observed that NLGN2-OE animals spent less time keeping down the intruder compared to controls with the empty virus. Kohl *et al.* [72] increased the overexpression of NLGN2, particularly in the dorsal hippocampus of rats, by using an adeno-associated virus, and observed behavioral changes in terms of reduced novelty-induced exploration and decreased offensive behaviour. The hippocampus may be involved in aggression-related behavior. Considering the findings of Kohl *et al.* [72], it must be stated that individuals with an overexpression of NLGN2 in the hippocampus show increased inhibition in novelty-induced exploration and reduced aggressive behavior.

8 Monoamine Oxidase

Monoamine oxidases A and B (MAOA and MAOB) are enzymes encoded by genes located on chromosome Xp11.3 [77]. Both MAOA and MAOB share a common promoter and both play a significant role in the metabolism of biogenic amines of the central and peripheral nervous system. While MAOA oxidizes serotonin, epinephrine, and norepinephrine (NE), MAOB fulfils a key role in dopamine and phenylethylamine metabolism. An imbalanced metabolism of serotonin and norepinephrine was observed in mice without the MAOA gene. The consequence of the MAOA knockout in the murine model was an increase in aggressive behaviors [78]. The corresponding observations in humans indicated a rise in aggressive behaviors in the case of MAOA gene mutation [79].

The results of research into the variable number of tandem repeats (VNTR) located in the promoter of MAOA seem promising. According to Sabol *et al.* [80] and Decker *et al.* [81], the product of the MAOA-VNTR can be five alleles consisting of 2, 3, 3.5, 4, and 5 30-bp tandem repeats. The relatively rare VNTR allele with 2 repeats displays the lowest expression of the enzyme, corresponding only to 25–30% of the activity of the MAOA promoter in allele 4 [82]. When this allele was present, a two-fold increased level of delinquency and violent delinquency compared to the carriers of other MAOA-VNTR variants in men, and similar although weaker symptoms in women, were observed [82]. It has been known that allele 2 of the MAOA-VNTR represents the most "criminogenic" variant of monoamine oxidase A.

In the case of alleles with 3 and 4 repeats, respectively, low and high expression levels of MAOA can be observed [80,81,83]. Males with 4 MAOA-VNTR repeats featured a high activity of the enzyme and were less violent than males with a low activity of MAOA [84,85]. A few years ago another new polymorphic VNTR in the promoter region of MAOA was identified, consisting of 10-bp tandem repeats [86], which enhanced MAOA expression. Traumatic childhood experiences may leave permanent marks in the nervous system that would lead to aggressive behavior in adulthood. Peripuberty stress leads to abnormal aggression, altered amygdala and orbitofrontal reactivity and increased prefrontal MAOA gene expression [87]. Studies on rats showed that male rats that experienced traumatic stress in the early life, displayed constant and increased levels of aggression towards non-threatening rats [88]. Similar behaviors can be observed in restless and even brutal individuals. In difficult life situations, activation of the periorbital cortex can be noted in healthy individuals. It is thought to reduce aggressive impulses and help maintain normal interpersonal relationships. The activity of the periorbital cortex was found to be very low in rats, which can lead to reducing the animals' abilities to alleviate aggressive impulses. In aggressive humans, this activity is also very low, and thus their ability to inhibit aggressive impulses is decreased. Aggressive humans also feature an increased activity of the amygdalae (brain regions responsible for emotions, fear and anxiety) as well as modified junctions between the amygdalae and regions responsible for decision-making. These modifications are accompanied by a greater expression of monoamine oxidase. Treatment of rats with MAOA was shown to restore normal social behaviors and reduce the stress level in animals which had experienced stress.

Polymorphic variants in the monoamine oxidase A may be of particular importance due to the relationship between these polymorphic variants and anatomical changes in the limbic system of aggressive humans. Furthermore, functional variants of MAOA are capable of mediating the influence of environmental factors on aggression-related traits.

9 Vasopressin receptors

Vasopressin (AVP) and its vasopressin homologs are involved in the regulation of social behavior [89-93]. Particularly in mammals, AVP participates in aggression expression. Vasopressin affects aggressive behavior through two separate brain receptors: vasopressin 1a (AVPR1A) and vasopressin 1b receptors (AVPR1B). A disruption of the AVPR1B gene reduces male-male aggression and reduces social motivation.

Studies on the influence of AVPR1B on regulation of aggressive behavior in knockout mice yielded some interesting results [94]. Wersinger *et al.* [95] examined maternal aggression and predatory behavior in knockout mice with genotype AVPR1B −/− , *i.e.* with the AVPR1B gene removed. The research was conducted on a wide scale and focused on a variety of behaviors, including the impact of AVPR1B removal on manifestations of aggression. Studies on rats revealed differences between AVPR1B and AVPR1A, as the former is expressed to a lesser degree than the latter [96]. Wersinger *et al.* [95] noted that "attack behavior toward a conspecific is consistently reduced in AVPR1B −/− mice". Predatory behavior is normal, suggesting that the deficit is not due to a global inability to detect and attack stimuli" [95].

10 Aggression in sport: necessary or undesired?

Sport activities have been found to decrease aggression. This effect persists both in combat sports and in non-aggressive sports, e.g. synchronized swimming [97]. In their research on the effect of variants of the serotonin transporter gene (5-HTT) on aggressiveness in athletes, Sysoeva *et al.* found that in female athletes, the SS genotype was associated with higher aggressiveness and low negativism, whereas, quite unexpectedly, male athletes with the LL genotype were more aggressive than male athletes with the SS genotype.

In men, the cerebral processes that are presumed to underlie aggressiveness were found to be related to 5-HTT gene variants. The HP component of the cerebral potential responsible for automatic detection of differences was increased, as well as the P3a component responsible for involuntary attention and cognitive control. This suggests that carriers of the SS genotype use more cognitive resources to process information. This may be because the stimulus itself seems to be more "complex," which results in the involvement of additional resources of the frontal cortex. It may also be assumed that carriers of the SS genotype tend to analyze the incoming information more deeply. This more "serious" analysis of external information may underlie their refraining from impulsive behavior, which is often aggressive [97].

As mentioned above, human aggression/impulsivity-related traits are influenced by complex genetic and non-genetic factors. On the basis of this knowledge, let us consider now whether aggression in sport is necessary or unwanted.

There is no doubt combat athletes include aggressive individuals practicing boxing, judo or non-Olympic combat sports such as MMA, PRIDE FC, *etc.* It is also beyond doubt that aggression can be (i) a challenge, and (ii) a disadvantage. First, let us consider a soccer match played between two equal-level teams, e.g. Poland and Ukraine, in which the aggressive play of the Ukrainian team, at the risk of a number of players being sent off, brought them a 3:1 victory against the conservatively and apprehensively playing Polish team. The risk assumed and taken by the Ukrainian soccer players was high and their play was aggressive and momentarily brutal, but also motivated, ordered, deliberate, but in the consequence was effective. Combat sports coaches, especially boxing coaches, say that a sport fighter must have the pit bull nature. If they do not, let them take up golf. In their predicting of match scores, experienced sports journalists often speculate about which of the teams is "more hungry".

George Orwell, in his essay The Sporting Spirit published in Tribune [99], made the following observation: "People want to see one side on top and the other side humiliated, and they forget that victory gained through cheating or through the intervention of the crowd is meaningless. Even when the spectators don't intervene physically they try to influence the game by cheering their own side and "rattling" opposing players with boos and insults. Serious sport has nothing to do with fair play. It is bound up with hatred, jealousy, boastfulness, disregard of all rules and sadistic pleasure in witnessing violence: in other words it is war minus the shooting" [98]. In modern contact sports, particularly in competitive team games, coaches take account of aggressive tactics. It can be thus assumed that, while complying with sports rules, in many cases aggressive behaviors have become literally indispensable.

The methods of raising aggression expression are well known. They include locker room pep talks, warrior rituals, e.g. Haka, or application of legal and illegal dietary supplements such as testosterone. In our view, what is more interesting seems to be methods of lowering rather than raising aggression levels. They can be divided into: 1) focusing attention, *i.e.* concentration; 2) shifting attention, *i.e.* drawing an impulse to another area, e.g. gym exercises; and 3) tonic supplementation.

Can the question in the title be answered unambiguously? On the one hand, there is much evidence that aggression is useful in contact sports such as football, rugby or handball, in which players try to exert pressure on their opponents. Thoughts like "destroying", "leveling", or "obliterating" do cross players' minds during the game. On the other hand, there are situations where excessive aggression can ruin a match (Zidane's headbutting Materazzi) or a promising sports career.

In a popular view, combat sports are compared to full-contact team sports. Is this comparison really valid? In combat sports that use strikes, one may encounter a number of aggressive fighters, although not being in the highest ranks in their respective weight categories. In grappling sports, however, aggression could be a serious disadvantage. A successful combat sport athlete must not be faint-hearted, although there have been cases of elite boxers known for their timidity. Knowing that a fight is regulated by strict rules, a combat sport practitioner can use the opponent's aggression to his own advantage, on the condition this aggression is followed by chaotic and unconsidered actions. In fact, many combat sports are based on the premise that the opponent is the attacking party, while the defending athlete transforms the opponent's energy of attack to his advantage. Some of us may still recall Akiro Kurosava's movies in which an aggressive Japanese martial art student swings his arms and legs around a calm, almost passive, master, who skillfully avoids the student's blows. This is all staged poetics, but one may assume that sport is a slightly exaggerated reflection of daily life in which a rapid increase in aggressive behaviors can be noted. These behaviors can include aggressive tailing of a slow-moving car driver, or making rude gestures. An interesting observation was made by Kalina, who stated that regular physical activity lowers the level of aggression in 20-year-old students [99].

It seems paradoxical that martial arts training can, in effect, reduce the aggression level in athletes. This, however, really depends on the athletes themselves, their coaches, parents and their upbringing, which influences the patterns to follow. The question is also whether they seek in sport its true essence, or merely treat it as a channel for accumulated aggression. Although the authors of the present article used to train in combat sports and noted relationships between aggression and success in sport, the literature does not explicitly confirm their existence. There are, on the other hand, study reports on team games such as handball, revealing positive correlations between the players' aggression and the number of scored goals [100].

11 Conclusions

Aggression is conducive to the incidence of a particular genetic profile, and a serotonin deficit might be a cause of aggression. Other potential compounds involved in aggressive behaviors include norepinephrine, dopamine, GABA and COMP. Smaller differences in aggressive behaviors can be noted between male and female athletes relative to that observed between non-training men and women. Present-day coaches of competitive sports such as ice hockey, American football, rugby, soccer, water polo, handball and combat sports involving aggressive tactics or even physical violence are fully aware of the possibility of disciplinary penalties during a game, or even loss of points for a dangerous use of force.

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