The psychobiology of aggression and violence: bioethical implications

José Luis Díaz

Introduction

Bioethics is concerned with the ethical and moral aspects of life-related phenomena covered by biology and medicine. Topics such as the use of animals in harmful experiments, human responsibility within ecosystems, abortion, euthanasia or the use of stem cells for scientific and therapeutic purposes have been widely analysed and debated. Potentially, the field is very wide and can be applied in other socially relevant ways. One of these is the bioethical implications of cognitive and behavioural science, particularly the subject of aggression and violence. The relevance of this subject is clear, as very different moral and legal responsibilities may apply depending on whether aggression and violence are forms of behaviour that are innate or acquired, deliberate or automatic, understandable and justifiable based on causes, or how they relate to certain neurological and psychiatric conditions. In this and the above-mentioned topics, biological research and natural science theories are basic ingredients for reflections, arguments and decisions concerning ethics.

One of the original and recurring themes of analysis in behavioural science (in terms of the social role of aggression) is the apparent problem of determining whether aggressive behaviour is innate or acquired. This is a delicate issue because, were there to be a genetic and biological cause of aggression, it would be difficult to change this through social learning and we would be irredeemably condemned to violence. This view was heavily criticised by the Seville Statement (Adams 1991), with solid scientific arguments be difficult stating that, far from implying that aggression or violence were genetically determined, the behavioural, cognitive and neurological sciences showed that biological determinism is much less prevalent, which not only allows but obliges us to consider social elements as necessarily relevant in their processing and expression.

This study is a summary of certain psychobiology research topics that are relevant to aggression and violence and to the development of bioethical arguments. Special attention is given to the problem of distinguishing innate from acquired aspects of aggressive behaviour, the ethological understanding and definition of aggression, the biological basis for this behaviour and the link between emotions and aggression. The aim is for this platform to be used eventually to develop a bioethical argument

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founded on an empirical basis. The study does not tackle the issue of genetic influence on aggressive human behaviour, as this subject has been widely analysed by the renowned Nuffield Council on Bioethics (2002) in its report *Genetics and human behaviour: the ethical context*. That exhaustive and critical report makes it clear that genetic and acquired factors are involved in the expression of aggressive behaviour and that it is methodologically difficult to distinguish between them. The present study will thus be limited to certain behavioural, cognitive and physiological aspects of aggression. Before entering the substantive part of the study, the concepts involved must first be defined.

The term violence tends to apply to any event that occurs with unusual force, such as a typhoon, earthquake or train collisions. In terms of social interactions, we talk of violence when the following two conditions are fulfilled: the use or application of intense aggression that inflicts serious damage to people or their property and the use of this damaging force against what is considered natural, fair, moral or legal. In both senses of an attack that disturbs the natural state and violates a social rule, the application of the term would appear to be limited to human beings and a distinction should therefore be made between violence and aggression in terms that not all aggression is violent – only attacks that are harmful or destructive to subjects or objects and that threaten, weaken or break natural, social and cultural rules. We will see that certain incidents in primate groups could be classified as violent in some of these ways. To locate and understand the issue of violence, it is therefore vital to consider the concept and phenomenon of aggression. Aggression should in turn be analysed on the basis of at least two elements: a group of emotions and a group of forms of behaviour. This distinction is relevant because the emotions of anger, fury or rage that often precede and accompany aggression may or may not trigger behaviour or actions of directed force that risk producing or do produce pain, injury, fear or terror in the individual on the receiving end. For the moment this is the operational definition of aggressive behaviour that will be the subject of a critical analysis in this study.

Firstly, the subject of aggression is addressed in relation to an experimental model that adequately distinguishes behavioural from biological causes, which is a relevant issue for ethics. Secondly, the development of the concept of aggression in behavioural sciences is examined. Thirdly, the link between aggressive behaviour and the emotions that tend to trigger and accompany it (particularly anger and rage) is addressed in terms of both phenomenology and neuropsychology.

Aggression and social dominance in animals: regrouping by rank

One way of approaching the origin of complex forms of behaviour such as violence and aggression is to use experiments to determine whether the biological variables precede or follow the social behaviour. This can be achieved using various techniques, and one that appears relevant to the purposes of this study is the method of regrouping male mice by dominance developed by the author during various studies carried out in the 1980s. The method consists in creating groups of three mice in which, within a few days and with varying degrees and frequency of conflict, a relatively stable hierarchy is established with one aggressive and dominant mouse and two evasive and submissive mice. It is easy to recognise rank during attacks and fights in the cage by simply identifying the animal that attacks and the attacked animal that flees or the winner and loser in a contest. The behaviour and the actors can be easily identified, as the repertoire of attack and evasion behaviour is very well known in field and laboratory rodents thanks to the classic work of Scott (1966). To identify the individuals involved in the agonistic interactions, their back fur is marked with one of three different colours of permanent ink.

Once the ranking has been established and stabilised it is possible to carry out various biological measurements on the animals. However, measuring a variable does not reveal whether it is the cause or consequence of the dominant or subordinate behaviour. In order to establish causality the mice were regrouped using their rank to form new groups of three dominant males and three subordinate males by mixing animals of previously established and known ranks. After a few days, new dominances

were established in all groups, giving at least four combinations of successive ranks:

- dominant in the first and second grouping (D-D)
- subordinate in the first and second grouping (S-S)
- dominant first, and then subordinate in the second grouping (D-S)
- subordinate first, and then dominant in the second grouping (S-D)

Thus, if a biological variable is measured in animals in which the history of dominance is known, it is possible to establish whether it is a cause or consequence of the rank and the associated aggression or flight behaviour. The domination–subordination relationship is established mainly through the display of aggressive and submissive behaviour, which makes it a social phenomenon that results from the agonistic behaviour and also regulates it.

This strategy was used to establish that dominant mice have significantly lower cerebral enkephalin content than the subordinates (Díaz and Asai, 1990). It is well known that enkephalins are neurotransmitters and modulators involved in the central nervous mechanisms of reward and pain. The technique of grouping mice by rank demonstrated that the methionine-enkephalin content in the brainstem is much lower in doubly dominant animals (D-D) than in the repeatedly subordinate animals (S-S) and that the level falls dramatically once the dominant rank is attained by previously subordinate animals (S-D), while it increases considerably in mice (D-S) that lose the dominant rank from the first grouping to become subordinate in the second. It is possible to conclude that behaviour associated with hierarchical rank (namely, the aggression and attack involved in dominance and the submission and flight involved in subordination) may bring about significant changes in the content of neuromodulators related to pleasure and pain in the brain. One interpretation of the results is that the neurological system for pain undergoes a preventive adaptation and coping mechanism in relation to the stress of injuries associated with subordination. Indeed, in these experiments there were a high number of injuries resulting from bites and cuts inflicted upon the subordinate mice by the dominant animals.

In order to further assess the time dynamics involved in losing and achieving social domination, the author carried out other experiments that were not published at the time. Data from one of these experiments are provided in Table 1.

Seventy-five 12-week old male albino BALB-c mice were divided into 25 groups of three. Every day the fights and attacks and the winners and losers of each dispute were recorded for 1 hour. The consistent winners were considered dominant on the fifth day of consecutive victories. After 3 weeks, hierarchical social structures were detected in 21 of the 25 groups, which meant there were 21 dominant mice each with two subordinate mice (42 subordinate animals). In the remaining four groups there was no aggressive behaviour, attacks or injuries. On day 22 of the experiment the animals were regrouped into seven groups of three dominant mice, 14 groups of three subordinate mice and four groups of non-aggressive mice (third column of Table 1). Their behaviour continued

TABLE 1. Redistribution of groups of three male BALB/c mice based on dominance hierarchy

First grouping (days 1–22)		Regrouping by rank (days 22–43)			
Initial	*Result*	*Regrouping*	*Result*	Final distribution	
25 groups of 3 mice	21 hierarchical groups	7 groups of dominants	5 hierarchical groups	5	5 D-D
				10	S-S
			1 non-aggressive group		3 D-N
			1 uncertain group	3	D-U
		14 groups of subordinates	5 hierarchical groups	5	S-D
				10	S-S
			6 non-aggressive groups	18	S-N
			3 uncertain groups	9	S-U
	4 non-aggressive groups	4 non-aggressive groups	2 non-aggressive groups	6	N-N
			2 uncertain groups	6	N-U

Ranks: D, dominant; S, subordinate; N, non-aggressive; U, uncertain rank.

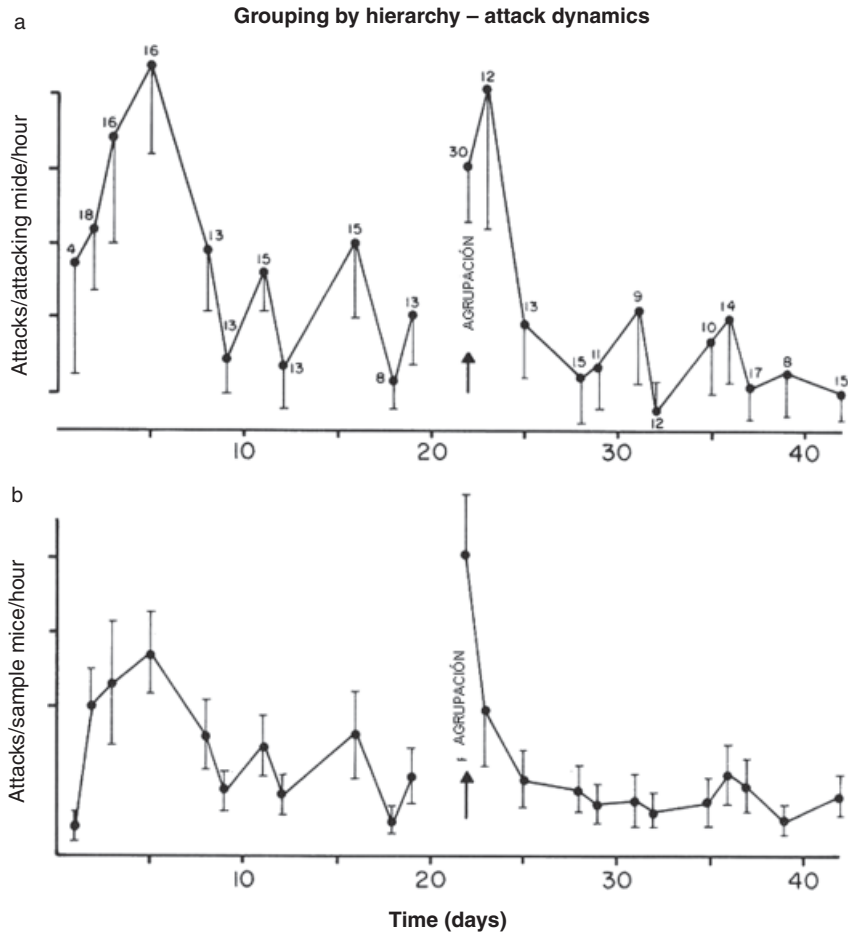

FIGURE 1. Time dynamics of attacks in a study involving regrouping based on dominance rank

to be recorded in the same way. In many of the new groups there was a new social structure with a dominant mouse and two subordinates. The results are presented in the last two columns of Table 1. New ranks were recognised in five of the seven groups of dominant mice, while in the other two groups the ranks were uncertain or there were no fights. In contrast, only five of the 14 subordinate groups showed structures of dominance. In six groups there were no fights or attacks, while in the other three groups there were fights but no winner or dominant mouse was established. Lastly, in the four groups that had displayed no aggression in the first round, two groups engaged in fights but these did not lead to an identifiably dominant animal, while in the remaining two groups social calm continued to reign.

These results of regrouping by rank indicate considerable variability in the expression of aggression and submission in mice, despite the fact that they come from a laboratory strain that is over 99 per cent genetically identical. This variability in behaviour necessarily implies acquired factors of an epigenetic, learned or circumstantial nature that depend on the combination of certain individuals for a dominant rank to be established with a stable social structure based on the display of agonistic aggressive and submissive behaviour.

An analysis of the aggression dynamics in the groups reveals learned factors in aggression. Figure 1 shows the time of the experiment along

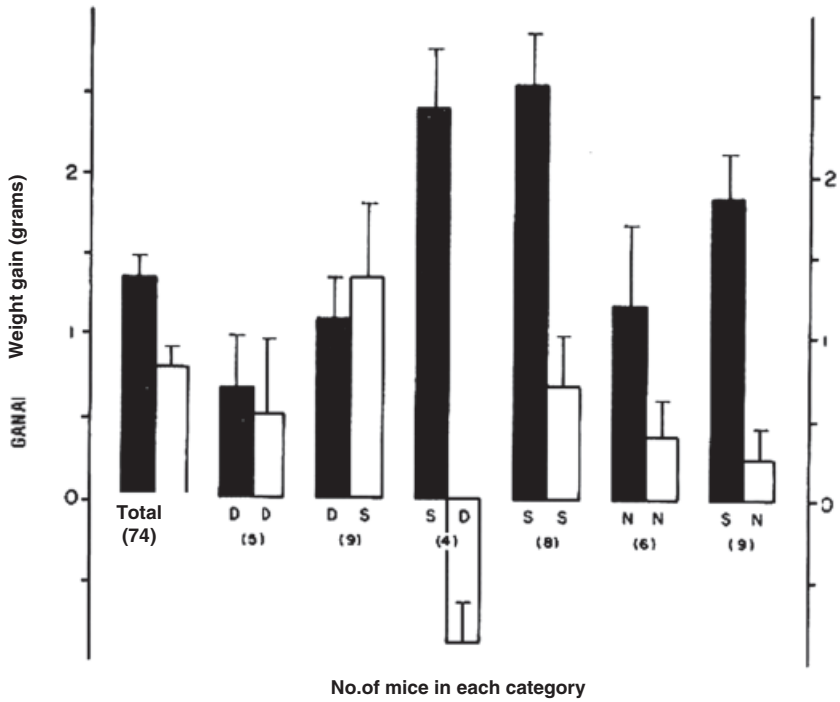

FIGURE 2. Weight gain in dominant (D), subordinate (S) and non-aggressive (N) male mice by dominance rank showing ■, initial grouping (days 1–22) and □ regrouping by hierarchy (days 22–43)

the x-axis and the attacks are recorded along the y-axis. In the first grouping (days 1–20), there was little aggression on the first day but it increased and reached its peak on the fifth day (with an average of 1.4 attacks per hour for the entire sample and almost six attacks per hour by the 16 attacking mice). From that day, the attacks decreased rapidly before stabilising from day 10, when the groups settled down into a pattern of one dominant animal and two subordinates with little detectable aggression. The attack dynamics were very different for the grouping introduced from day 21. This time around, aggression peaked on the first day, with over two attacks per mouse and 30 contenders attacking nearly six times an hour. In contrast with the first grouping, dominance ranks were already established by the second day and subsequent aggressions dropped to levels lower than in the previous period.

The Figure 1b shows the daily average of attacks recorded for the 75 mice of the sample, while Figure 1a shows average attacks by mice that displayed aggressive behaviour. Figure 1a shows that the number of attacking mice is above average. The vertical bars in each group represent the standard error.

These data point to several conclusions in terms of the innate or acquired nature of social aggression and dominance in mice with practically identical genomes. The first conclusion is that this behaviour has a strong learned component, demonstrated by the exponential and rapid aggression dynamic in the groups made up of experienced animals, compared with the dynamic in the inexperienced first grouping. The formation of social structures was much more rapid and efficient in the second grouping, and aggression plays a stabilising roles as group stability is higher when aggression is established more efficiently and with lower stress and injury costs in implementing and maintaining the social structure.

Another interesting variable was bodyweight, as measured once a week. Figure 2 is a histogram of gains in bodyweight in grams

during the first grouping (black bars) and the second grouping (white bars) for all mice from the sample grouped into seven sets with known dominance. The far left column shows the weight gain for the entire sample. The mice gained 1.4 g in the first grouping and 0.8 g in the second, which is what would be expected given their young age. The next few bars show that the dominant animals (indicated by D) put on less weight than the subordinates (indicated by S). As a result, those who maintain dominance in the second round (D-D) gain less weight than those who lose dominance (D-S), while the subordinates who become dominant in the second round (S-D) lose weight in their new role. Those who remain subordinate (S-S) gain some weight in the second group, in a similar way to those who remain dominant. Lastly, the non-aggressive mice have intermediate weight gain, fairly similar to the general population.

These data show that dominant mice gain much less weight than subordinates in small groups with established dominance. A change in dominance exacerbates this tendency, such that the dominant mice who become subordinates gain more weight than any other group while subordinates which become dominant are the only subgroup to lose weight. The results demonstrate that there is a differential physiology of dominance and submission, which is probably closely linked to social stress. Dominant animals in many species are known to show more stress than subordinates, based on plasma cortisol levels and reactivity to stressful stimuli (Morell 1996). Although thanks to their social position dominant animals have privileged access to and sometimes control over food sources they gain less weight than subordinates. The reason may be an alteration in intake or metabolism, which are hypotheses worthy of future study.

In summary, the experiment shows the following: (a) there is a great variability in aggression and submissive behaviour seen in individual mice from the same laboratory strain, (b) social dominance associated with aggression and social subordination related to flight cause significant physiological changes that affect bodyweight and the level of neuromodulators associated with pain and reward, and (c) aggressive behaviour associated with the dominant rank and the formation and establishment of a social structure has innate and learning-based acquired components that combine in an increasingly effective way to establish and maintain the social structure.

Aggression in behavioural science

The definition of aggression in terms of action and behaviour has proved difficult not only in human sciences but also in animal behavioural science. Classic ethology from the 1950s and quantitative ethology from the 1970s faced various problems concerning aggression, even though it was a key interest of some of their most famous pioneers, such as Konrad Lorenz (1963). One fundamental problem that ethology had with the concept of aggression was that it is not, strictly speaking, an event, but rather an interpretation of various forms of behaviour. While it did not appear problematic initially to define attack and fighting behaviour among animals of the same species as aggressive it was preferable to refer to a long list of forms of attack and defence behaviour under the general heading of agonistic behaviour as persuasively argued by Scott (1966). Thus, the category of agonistic behaviour adequately covers fight behaviour, with more emphasis on social interaction than in the individual display of certain actions. As a result of this emphasis on the interaction rather than on individual behaviour, the term aggression not only covered the attacker–victim pairing but also made it possible to focus on behavioural units; in other words, particular actions displayed by the attacker and the attacked during an agonistic encounter.

Behavioural units are specific movements or actions with varying intensity, duration and muscle tension that constitute a recognisable morphological expression in members of a species (Díaz 1985). Identifying behavioural units made it possible to produce ethograms to catalogue behavioural units for general activities such as feeding, sexual behaviour and, in this case, aggression. This advance proved that aggression and agonistic behaviour are sets of particular actions with variable expressions and intensity. For instance, an attack or fight with its

range of bodily contact of varying intensity may be preceded by threatening forms of behaviour consisting of acts that feign or warn of attacks. Gestures such as staring, raised eyebrows, bared teeth, growling, feints or partially hitting the opponent with a hand or the entire body are forms of behaviour that threaten the other individual. These types of behaviour are defined exclusively on the basis of their morphology or form of expression, a distinction that proved to be another substantial advance, as the initial task of empirical research for quantitative ethology was to specify an ethogram or catalogue of forms of behaviour operationally defined as morphological behavioural units with no interpretation of intention. This fulfilled the methodological requirement of forms of behaviour counted and measured by trained observers, in order to produce significant agreement and reliable quantitative records of behaviour (Altmann 1974).

Defining measurable units of behaviour as morphological implied that the function of behaviour defined by its motor pattern was excluded from analysis, as the function of behaviour is very different from simply listing its forms of expression. Aggression involves a functional inference of a series of morphologically defined acts, that cannot be used to deduce cognitive or emotional causes (including intention). Subsequent ethology made a further useful and insightful distinction by showing that, in order to define the function of any behaviour in these terms it was vital to record or analyse not only the expression of specific actions by the actor but also the response of the receptive party and the circumstances of the interaction – a notion that has been recently applied in the analysis of human aggression (Cohen *et al*. 2006). Once these requirements had been fulfilled, the objections to ethology based on anthropomorphism or an interpretative bias of animal behaviour were reasonably rebutted, leaving the way clear for a more rigorous science.

At the time when these methodological requirements were being established, in *Psychology of Aggression* (1976) Moyer distinguished eight types of aggression that are relevant to any analysis of aggression and its implications for human bioethics. These consist of the following types of aggression, according to the causal stimuli and circumstances in which the agonistic encounter takes place:

1. Predatory aggression associated with hunting (usually of different species), such as the muricide behaviour of cats.
2. Aggression caused by fear as a defence against confinement, such as the response of prey when the predator's attack is inevitable.
3. Dominance exercised by a higher ranking animal towards a lower ranking animal in groups of the same species. This aggression is usually inhibited or limited by submissive behaviour.
4. Aggression triggered by irritating stimuli in stressed animals.
5. Territorial aggression during invasions of living space.
6. Aggression by females (and sometimes males) towards an intruder close to their offspring.
7. Aggression directed at an object of frustration.
8. Aggression associated with sexual competition.

The classification is not based on identifying, describing or quantifying particular forms of behaviour but rather by distinguishing the circumstances in which these and other kinds of behaviour occur particularly the stimuli by which they are triggered. Moyer's list is not exhaustive and other categories could be added, such as the disciplinary aggression of parents towards offspring, xenophobic aggression towards strangers of the same species or aggression directed at the individual considered to have violated certain principles. This framework of reference for causal stimuli is therefore indispensable in distinguishing the functions of behaviour, and has social as well as psychological and biological components. Distinguishing between aggressive forms of behaviour makes it clear that, depending on the context, aggression has very different functions and equally different and not always destructive motives (Cohen *et al*. 2006).

Beyond the sphere of methodology, ethology has repeatedly used the contributions of Konrad Lorenz (1963) to show that aggressive behaviour is essential in any social group of animals in their natural environment. Aggression expresses a necessary skill for acquiring and maintaining roles and hierarchical status in the social structure of many species. Those animals

that display a greater amount of aggressive behaviour also exchange more friendly or affiliative forms of behaviour, giving rise to complex relationships and the social structure that characterises many species. In disputes over territory or sexual competition the aggression displayed is usually subdued when the other individual shows signs of flight or submission. In groups of animals of the same species aggression has a very similar function, in that submissive behaviour defuses the attack, and this forms the basis for the bonds and relationships of dominance and subordination that make up the social structure, thanks to cohesive forces for affiliation and repulsion forces in the form of aggression. Aggression and affiliation (or reconciliation) are therefore normal and necessary elements for the formation and maintenance of social structures in animals. The positive aspects of aggression include limiting the harmful actions of others. Social learning is essential for testing and learning how and when to channel aggression, so that it remains a resource that is more beneficial than damaging in terms of the adaptation of both the individual and of the social group.

Unlike the usual and generally favourable role of aggression, however, periods of intense, strange or uncontrollable aggression have been reported in groups of primates, in circumstances very different from the usual aggression that is part of social co-existence in groups of the same species. According to the work of renowned primatologist Jane Goodall (2000) on the chimpanzees of Gombe and the author's own work on captive stump-tailed macaque monkeys in Mexico City (Díaz 1985), at some point troops of these primates depart from the usual rules of communal living and carry out ferocious and apparently unmotivated attacks that do not subside when the opponent submits and that can include infant kidnappings or cannibalism (which tend to be rare in normal communal conditions). These episodes suggest that certain forms of human behaviour that we define as violent based on its intensity and departure from what are considered natural limits of behaviour could be present in our close biological relatives. Many species have also been described as having hyper-aggressive males who continue to attack even when the victim displays signals of submission. These characteristics can be artificially selected to produce hyper-aggressive strains but it is significant that this does not happen naturally (Carey 2002). Such episodes and evidence are highly relevant to the discussion of the nature of aggression and the distinction between different types of aggression, rules and justification. In principle, the results show that certain behaviour that is considered to be violent among human beings, because it transgresses what are considered to be natural and socially acceptable limits and because of its destructive intention, appears to be present in other primates.

In addition, it has been extensively documented that conflict strategies among animals (and primates in particular) cover not only agonistic encounters but also, necessarily and concomitantly, many forms of affiliation and reconciliation (de Waal, 1989).

Emotions and aggression

One of the most pertinent issues in the ethical implications of violence and aggression is the involvement of a group of cognitive processes and emotions as causes, accompanying states or results of forms of behaviour that are defined as aggressive based on their morphology or context. The relationship between them is the key to the circumstances that enable us to distinguish between types of aggression and they are a relevant basic research topic as they involve certain biological aspects specifically the cerebral bases for these emotions and kinds of behaviour. This section tackles some emotional aspects of violence and aggression.

As an interactive concept, and in terms of the distinction between the form and function of the behaviour, aggression implies that the emotion of anger can be distinguished from the action of attack, as they do not necessarily go hand in hand particularly in humans but probably also in other primates. For example, there can be destructive attacks without anger or rage on the part of the attacker, while some individuals may not consider another's action that causes them pain and injury as aggression. Indeed, attacks without anger are common in what are considered extremely violent human actions such as certain acts of war or violent behaviour displayed by people who are not

angry but who feel enjoyment and pleasure in harming others. Events where anger or fury are not linked to the attack usually occur in human beings as part of the circumstances and feelings known as vengeance, retaliation or revenge. Aggressive forms of behaviour and emotions that are a delayed reaction to an insult or loss are very common in all cultures and are often strongly supported by many cultural and religious traditions. The emotional dimension or causes for the attacker may be highly variable and difficult to determine, although they are of great interest for considering and analysing the process and nature of aggression in a more complete way.

Any discussion of the accompanying mental states and causes of aggression must be preceded by a brief analysis of the emotions most commonly associated with aggression such as rage and anger, unpleasant and basic feeling showing arousal and the universal display of facial expressions in humans. Universal facial expression and its pan-cultural recognition have established the emotion of anger as one of the six basic emotions of humankind (Ekman and Friesen, 1975). However, it should be pointed out that facial expression does not imply emotion, as it can be assumed or adopted deliberately. Human observers (especially women) are highly skilled at deciphering and distinguishing between spontaneous and simulated expressions.

The emotion of anger tends to arise in response to a series of perceptions and induces a series of actions to correct these causes. Two types of stimuli trigger emotions of anger: actions of others perceived as harmful, damaging or offensive, and frustration in achieving an objective. In the first case, anger arises from a perceived loss or injury attributable to another's intention that is judged to be unfair. This distinction based on judgment is crucial, because a similar loss that cannot be attributed to a wilful agent leads to sadness rather than anger. Anger can vary in intensity from irritation and disturbance to indignation or rage. There are not only variations in intensity but also in the form that anger takes including moral indignation when one's rights have been violated, exasperation at having too much to cope with or revenge as a delayed and deliberately aggressive response to an offence. Thus, there is a parallel that has not been sufficiently analysed between the different types of aggression based on cause and circumstance and types of aggression based on emotions and judgments.

Above and beyond its causes and qualities, anger is an emotion that usually precedes and accompanies aggressive behaviour (particularly sudden and uncontrolled attacks). In some episodes of anger the individual loses control and the emotion manifests itself as rage that results in attacks on or destruction of people and objects. Fury is thus identified as a devastating and uncontrolled behavioural expression of the emotion of anger. The state of intense emotional arousal makes individuals lose control of their behaviour, which is usually governed by some assessment of utility and by intention. During an attack of rage, the communication and processing of cognitive information are inefficient. This gives rise to the expression, ''blind rage'', as perception is altered because sensory information is not adequately processed, and the event can seem hazy or difficult to recall when the person attempts to remember it afterwards.

These types of impulsive and explosive acts can occur in any individual at one or several times in their life, and it is difficult to establish acceptable boundaries of what is normal, standard, customary or sensible. For instance, the controversial Diagnostic and Statistical Manual of Mental Disorders describes an ''intermittent explosive disorder'', where the anomaly is that episodes or attacks of rage are *very frequent*, resulting in *significant* damage or injury, with a level of aggression *disproportionate* to the stimulus and that is not explained by other disorders such as an anti-social personality, mania or temporal lobe epilepsy. The people who have this supposed disorder not only react to certain situations with uncontrolled and excessive rage but also experience a sense of relief during the attack and subsequently remorse over their actions (Moeller *et al*. 2001).

Some authors, such as Beck (1999), suggest a distinction between a destructive and constructive way of dealing with the emotion of anger. The difference lies in the voluntary control that is exercised, not over the emotion (as this is usually uncontrollable), but over the behavioural expression. The loss of control and the blind expression of rage can be very destructive, while controlling this expression

enables people to channel the arousal of anger into constructive actions. Beck emphasises the opportunity offered by anger and other emotions to reassess aspects such as the reality of the supposed loss, the value of the object, the perception of dignity, humiliation, autonomy, power, privacy or territory that are perceived as violated. Similarly, anger is also constructive in that it enables one to reassess the person blamed for causing the anger, particularly the degree of responsibility that can be assigned to that person in terms of his or her own motivations and intentions. Beck considers that most episodes of anger, hate and violence arise out of false perceptions and interpretations and suggests that a critical analysis of the circumstances and agents that lead to the emotion can be used to adjust the understanding and reframing the problem and the attitude.

The issue of rage and its control is clearly relevant in any argument over human responsibility in violent acts, in terms of the bioethics of aggression and violence. In principle, violence can be said to be unjustifiable with reference to rage, as evidence suggests it is possible to develop control over the expression of this emotion through learning and the application of rules of behaviour.

Physiological basis for aggression

A group of Spanish researchers (Gil-Verona *et al*. 2002) has carried out a widely documented review of the biological basis for aggression and violence and their work enables some conclusions to be drawn about previously established knowledge in this field. There is considerable scientific evidence for the role of testosterone as a promoter of aggression. Testosterone is part of a set of endocrine and cerebral factors that are closely linked to reproductive behaviour, which clearly and understandably relates to competition for territory and sexual partners. Episodes of aggression and anger attacks are therefore much more common in adolescence among males of various species from fish to primates. This also includes human males and testosterone has therefore been described as a crucial contributing factor. There is some evidence that androgens are restricted not only during puberty but that they also have an impact before birth, as experimental prenatal androgenisation results in a higher incidence of aggression in adult males. Similarly, prepubescent boys have been documented as being more aggressive than girls and this is paralleled socially by the way in which some societies tolerate or even promote male aggression.

The work of Gil-Verona and his colleagues reviews and updates a vast range of information by showing that certain biological (and particularly brain-related) anomalies predispose individuals to aggressive behaviour. One of these is temporal lobe epilepsy, which is a non-convulsive localised dysfunction that involves the automatic expression of violent behaviour as a result of a functional alteration to the temporal lobe and the amygdaloid nuclei: two neurone groups located deep within the lobe that are strongly involved in the emotions of anger and fear (Gil-Verona *et al*. 2002). In the first half of the twentieth century neurophysiology established that the stimulation or removal of these nuclei produced aggressive or fearful behaviour, depending on the portions of the amygdala involved. Since that time it has been confirmed that the temporal amygdala does not produce aggression by itself but rather acts as part of more complex systems involving other areas of the brain. It should be pointed out that the amygdala has a mutually inhibitive relationship with the frontal lobe, so that if one area dominates then the other is diminished. As a result, while a predominant activity of the amygdala produces rage-related emotions and behaviour, a predominance of the frontal lobe produces placid behaviour.

One spectacular case of accidental injury of the frontal lobe confirmed this theory of mutual inhibition. Phineas Gage, a rail worker from Cavendish, surprisingly survived for 12 years after a metal bar pierced his cheek, penetrated his skull and passed through the skullcap, destroying his left eye and frontal lobe in the process. Following this unusual and tragic accident, the railway operator changed from a pleasant and peaceful man to a silent, irritable and violent one. The current interpretation of this famous case (Davidson *et al*. 2001) is that the destruction of the frontal lobe prevented the inhibitory modulation that it exercises over the

amygdala, so that the emotions and behaviour of rage were triggered more easily.

The frontal lobe is involved in many kinds of socially learned behaviour and constitutes an area of the brain that can be used to regulate aggressive behaviour by reference to social rules of a moral nature. In support of this idea, individuals who display particularly violent behaviour have been identified as having damage or dysfunction in the pre-frontal cortex (Best *et al.* 2002), including a reduction in the levels or transmission of serotonin, a neurotransmitter involved in depression, eating patterns and aggression. There is a well-documented decrease in the transmission of serotonin and an increase in dopamine transmission during animal aggression and this may be a neuro-chemical factor in aggressive human populations (Miczek *et al.* 2002). Although these findings are usually interpreted as causes of violent behaviour, the evidence suggests that they may be secondary, since certain forms of behaviour can modify the functioning of brain circuits and neurotransmitters involved in stress and reward. Neurochemical systems are highly responsive to environmental situations and stimuli and kinds of behaviour such as aggression or violent hyperaggression responds to a complex set of innate and acquired characteristics and biological, psychological and social variables.

Even in cases of genetic predisposition it could be said that genes do not cause behaviour inevitably or in a linear cause-and-effect way. Far from being a matter of simplistic genetic determinism, we know that experience, physiology and behaviour are dynamic factors that develop not as separate abstract entities but as part of processes of multiple interactions and complex integration that incorporate genes, experience and social rules. An argument against simplistic genetic predisposition is that, while genes do predispose people to certain behaviour, there are many mechanisms that inhibit the expression of this behaviour as enkephalisation progresses and the frontal lobe develops. Many of these mechanisms are cultural in nature such as rules, ideologies or forms of behaviour. In a renowned book on the cerebral basis of violence, Debra Niehoff (1999) argues that each individual's encounters with their social and ecological environment have lasting effects on the neurobiological processes that underlie all behaviour and aggressive behaviour in particular.

Implications of basic research into aggression

The knowledge of ethology and cognitive neuroscience is vital in defining human aggression, as they reinforce the idea that a form of behaviour cannot be defined as aggressive purely on the basis of the motor pattern of an agent. Threats, posturing, facial expressions and even blows can manifest very diverse biological and mental functions – some very different from aggression. By way of illustration, consider the preliminary definition of aggression given above, that is the set of acts that threatens to produce or actually produces pain, fear or injury to another being. This definition is inadequate if we consider forms of behaviour that fulfil the criteria but are not aggressive. An injection fits the description, as it is a behaviour that produces fear, pain and injury to someone, yet it is not classified as aggressive. A tooth extraction or an operation is even more aggressive in terms of the pain and injury it causes. These examples illustrate the need, demonstrated by ethology, for the definition of aggression to include the receptor and the circumstances of the interaction. In the above-mentioned cases, although the person engaging in the behaviour matches the definition, the recipient considers the actions to be beneficial rather than harmful, as the circumstances of the interaction are not those of an attack but of treatment and the agent's emotions are not anger or rage but care and attention.

This means that aggression must be redefined so that behaviour seen as threatening or producing pain, fear or injury must be identified as such by the receptor or the cultural system in order to be classified as aggressive and the circumstances must be not only a deliberate attack but also a confrontation, flight or chase. Interpreting aggression in this way involves considering the agent and the recipient of the behaviour in order to define it, as it is not possible to consider only the person carrying out the behaviour. Actions can be considered as a whole and generically as attack behaviour, namely

behaviour directed against a recipient with the intention of striking or injuring the other party. Aggression is therefore an interaction not only because the recipient confronts the attacker but also because the recipient displays reactions to the attack such as fear, flight or counterattack. When it comes to analyzing aggression in the social context, recording such attack and flight is as important as recording the fight or confrontation (even for laboratory animals such as mice).

Far from assuming a reductionist stance on aggression, psychobiology and behavioural science provide an opportunity to consider and observe aggression not only as an enactment of certain actions by an agent but also as what is experienced by the party on the receiving end, and also mainly as an interaction between the two parties in contexts that clearly demonstrate the nature of this link and chain of actions as aggressive or non-aggressive. Behavioural science cannot and does not claim to go further in terms of the accompanying mental states or causes of aggression that are so important for understanding causes and consequences, and in turn tackling the ethical and legal implications of aggressive behaviour. Aggression has an undeniable neurobiological basis but this does not imply that it begins and ends with neurochemistry or brain physiology. A growing body of convincing evidence suggests that innate factors of behaviour (be they genes, brain circuits or neuro-chemical factors) do not by themselves define behaviour and nor do acquired factors such as learning, cultural norms or worldviews. Both types of factors interact from the outset to shape a development process that mutually defines beliefs or behaviour. Biological and psychological methods and social practices are therefore all partially effective in shaping behaviour in general and aggressive behaviour in particular.

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