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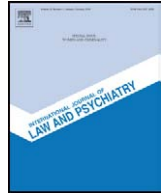


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Understanding human aggression: New insights from neuroscience

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ABSTRACT

The present paper reviews and summarizes the basic findings concerning the nature of the neurobiological and behavioral characteristics of aggression and rage. For heuristic purposes, the types of aggression will be reduced to two categories – defensive rage (affective defense) and predatory attack. This approach helps explain both the behavioral properties of aggression as well as the underlying neural substrates and mechanisms of aggression both in animals and humans. Defensive rage behavior is activated by a threatening stimulus that is real or perceived and is associated with marked sympathetic output. This yields impulsivity with minimal cortical involvement. Predatory attack behavior in both animals and humans is generally planned, taking minutes, hours, days, weeks, months, or even years (with respect to humans) for it to occur and is directed upon a specific individual target; it reflects few outward sympathetic signs and is believed to require cortical involvement for its expression. Predatory attack requires activation of the lateral hypothalamus, while defensive rage requires activation of the medial hypothalamus and midbrain periaqueductal gray (PAG). Both forms of aggressive behavior are controlled by components of the limbic system, a region of the forebrain that is influenced by sensory inputs from the cerebral cortex and monoaminergic inputs from the brainstem reticular formation. Control of aggressive tendencies is partly modifiable through conditioning and related learning principles generated through the cerebral cortex.

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1. Introduction

Violence is a major social and public health problem throughout much of the world. One report revealed, for example, that more than 3,000,000 violent crimes are committed annually in the United States alone resulting in costs of billions of dollars to society (Reiss, Miczek, & Roth, 1994). Although the causes of violence are manifold and no simple solution is likely, this problem may be somewhat ameliorated by understanding the root causes of violence, which include the neurological substrates and mechanisms underlying the expression of violent behavior.

Violence is influenced by cultural, environmental and social factors which shape the manner in which it is expressed (Eron, 1987). Nevertheless, it is likely that there are specific neural substrates underlying different forms of aggressive behavior. The neural basis of human aggression resembles that in animals such as the cat and the forms of aggression seen in humans parallel those observed in animals. Evidence in support of this view is discussed below.

An expanding body of data indicates that aggressive behavior appears as a component of numerous clinical disorders associated with

abnormal brain function, including affective disorders, schizophrenia, traumatic brain injury, brain tumors, complex partial seizures, encephalitis, cerebrovascular disease, Alzheimer's disease, and normal pressure hydrocephalus (Aarsland, Cummings, Yenner, & Miller, 1996; Bear, 1979; Falconer, 1973; Heimbürger, Small, Small, Milstein, & Moore, 1978; Hood, Siegfried & Wieser, 1983; Monroe, 1978; Monroe, 1985; Ounsted, 1969; Piacente, 1986; Serafetinides, 1965; Sweet, Ervin, & Mark, 1969; Taylor, 1983; Victoroff, 2009). An especially dramatic example is “episodic dyscontrol”—a poorly understood condition, in some cases attributed to complex partial seizures or hypothalamic tumors, in which an individual may physically or verbally assault another in response to little or no provocation (Monroe, 1978). This disorder has been described in both adults (Maletzky, 1973; Monroe, 1978) and children (Nunn, 1986), lending credence to the idea that the same neural substrate underlies aggressive forms of behavior over the course of brain development. A phenomenologically similar form of aggression is linked to specific regions of the brain, discussed below, in both humans and animals.

2. Aggression defined

For purposes of the following discussion, it is useful to first provide a definition of aggression. One definition that has been commonly applied with reference to the study of animal aggression was formulated by Moyer (1968). In this definition, aggression refers to “a behavior that

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causes or leads to harm, damage or destruction of another organism.” This definition includes many of the conditions typically associated with aggressive behavior, but fails to include those behaviors associated with “threat” or “hostility.” From a behavioral perspective, threat and hostility may appear to be separate processes (Kingsbury, Lambert & Hendrickse, 1997), but from a neurological point of view (as described below), these processes may be viewed as highly similar.

2.1. Classification of aggression

It is important to acknowledge from the outset that a controversy is brewing in the kitchen of aggression research. It is empirically obvious and universally accepted that aggression is not a unitary phenomenon and that there is more than one type of aggression. Some authorities promote a reduction of the many types of aggression to two-type model, others promote a multi-typed model, and still others emphasize that ideal types may be misleading, since forms of aggression are often mixed. Feshbach (1964) was among the first to champion to dichotomy between so-called “proactive” and “reactive” types of aggression. Definitions of aggression may also be derived from the operational procedures used for the study of aggression in animals. Such definitions were elaborated by Moyer (1968) and include the following categories: *fear-induced aggression* – aggression induced when an animal prevented from escape attacks another animal; *maternal aggression* – aggression of a mother when it perceives that its pups are threatened; *inter-male aggression* – aggression induced when a male (usually a rodent) is paired with a male of the same species; *irritable aggression* – aggression induced following exposure to a threatening or irritating stimulus; this form of aggression has been studied extensively in cats and is referred to as affective defense (or defensive rage); *sex-related aggression* – aggression commonly observed in humans and also described in animals in which the sexual act is accompanied by components of aggression; *predatory aggression* – a distinct form of aggression unrelated to those forms described above in which the attack response is triggered by the presence of a prey object within its visual field; *territorial aggression* – aggression induced following the entry of an animal (i.e., intruder) into the domain deemed to be established by another animal (i.e., resident); this model is frequently referred to as a resident-intruder model.

Yet human aggression is more difficult to pigeonhole. Inter-male aggression such as gang fighting, involves a mix of planning and highly charged affect. Territorial wars serve instrumental purposes but engage high nationalistic emotions. As Anderson and Carnagey (2004) admonished, dividing aggression into ideal types risks oversimplifying a complex aspect of animal behavior because (1) many commonly observed forms of aggression do not fit well with ideal types, (2) dichotomous theories do not fit with the known interaction between automatic and conscious aspects of decision-making and (3) mixed aggression is often observed.

That having been said, there is heuristic value in reducing the broad spectrum and diversity of aggression into two main categories. The first category is *affective aggression* (also known as reactive, defensive, or hostile aggression), which includes all of the forms of aggression with the exception of predation because they are associated with fear or threat. The second category is that of predatory aggression (also referred to as proactive, premeditated, or instrumental aggression), which is usually distinct from other form. A further analysis of these two forms of aggression, including the apparent parallel between similar forms of aggression in humans and other animals as well as their neurological bases, is considered below.

3. Neural basis of aggression and rage

Two of the models described above – defensive rage and predatory attack – have been studied extensively in the cat with respect to their underlying neural mechanisms. As noted above, these models comprise the prototypes of the models with respect to their neural

mechanisms. Therefore, a brief description of the substrates and neural mechanisms subserving the expression and modulation of aggression and rage behavior.

3.1. Defensive rage behavior

Defensive rage behavior occurs in nature in response to a threat by another animal of the same or different species. The basic characteristics of this response, as determined from studies in felines, includes marked hissing, flattening of the ears, lowering of the body, drawing in of the head, piloerection, stiffening of the tail which becomes motionless, marked increases in blood pressure and heart rate, and these behavioral and physiological changes are followed by paw striking at a conspecific (Leyhausen, 1979). One of the key features of this response is that it lacks planning and is highly impulsive in its nature, a characteristic that is common throughout the animal kingdom and present in humans as well (see discussion below).

Concerning the neurological basis of aggressive behavior, it is useful to distinguish between two different levels of neural substrates that govern the expression and control of aggressive responses. The first includes structures associated with the expression of aggression and rage and the second includes structures involved in the modulation or control of these forms of aggression (described below).

With respect to the regions of the brain associated with the expression of defensive rage, it is now well known that this response can be elicited by electrical or chemical stimulation of the medial hypothalamus or the dorsolateral region of the midbrain periaqueductal gray (PAG) (Siegel, 2005; Siegel, Roeling, Gregg & Kruk, 1999). It should be noted that earlier studies have shown that other regions of the forebrain, including the cerebral cortex, were not essential for the expression of this form of aggression (Siegel, 2005). Because this form of aggressive behavior (as well as predatory attack described below) can be elicited by brain stimulation, these responses serve as effective models for the study of neural mechanisms and substrates underlying these forms of aggressive behavior.

3.2. Predatory attack behavior

Predatory attack behavior in the cat in the laboratory can be elicited by electrical stimulation of the perifornical lateral hypothalamus, ventral part of the PAG and dopamine-producing ventral tegmental region of the midbrain (Siegel, 2005). Upon stimulation, the cat stalks the prey object, usually an anesthetized rat, and then bites the back of the neck of the animal until stimulation is terminated. The response is highly directed to the prey object and not to other components of the environment. In contrast to defensive rage behavior, there is little evidence of sympathetic activation aside from some mild pupillary dilatation. In addition, and in contrast to defensive rage behavior, this response requires planning and strategies to be employed in the attack, therefore suggesting that it is reasonable to assume that the cerebral cortex is typically employed in the attack sequence. The overall pattern induced in the laboratory is highly similar to that observed under natural conditions.

4. Limbic system and its functions

One of the most important regions of the brain that contributes to the modulation of aggression and rage is the *limbic system*. The limbic system is typically regarded as consisting of the hippocampal formation, amygdala, septal area, nucleus accumbens, ventral striatum, and parts of the prefrontal and anterior cingulate cortices. There are several unique features about limbic structures that contribute to their modulating properties upon aggression and rage. One characteristic of limbic structures is that each region receives tertiary sensory signals – auditory, visual, olfactory and taste or a combination of these signals. The transmission of these sensory signals through the limbic system endows

the central nervous system with the capacity to provide affective qualities to such signals. In this manner, a given signal is not neutral, but becomes associated with specific states of positive or negative emotions. The second feature is that limbic structures project their axons either directly or indirectly to the hypothalamus and/or the midbrain PAG. This key property endows the limbic system with the capacity to modulate and control the functions associated with the hypothalamus and PAG, including aggression and rage behavior. Specifically, stimulation of limbic structures has been shown to have profound potentiating or suppressing effects upon these forms of aggression in the cat (see Fig. 1).

4.1. Evidence of limbic system and hypothalamic involvement in aggression in humans

There is a wide body of literature implicating limbic structures and the hypothalamus in the control of aggression and rage in humans. The data is based upon studies involving neurological disorders in patients. These include behavioral correlates of temporal lobe epilepsy, sclerosis of the temporal lobe, tumors of the temporal lobe, other regions of limbic system, and hypothalamus. These studies are summarized in

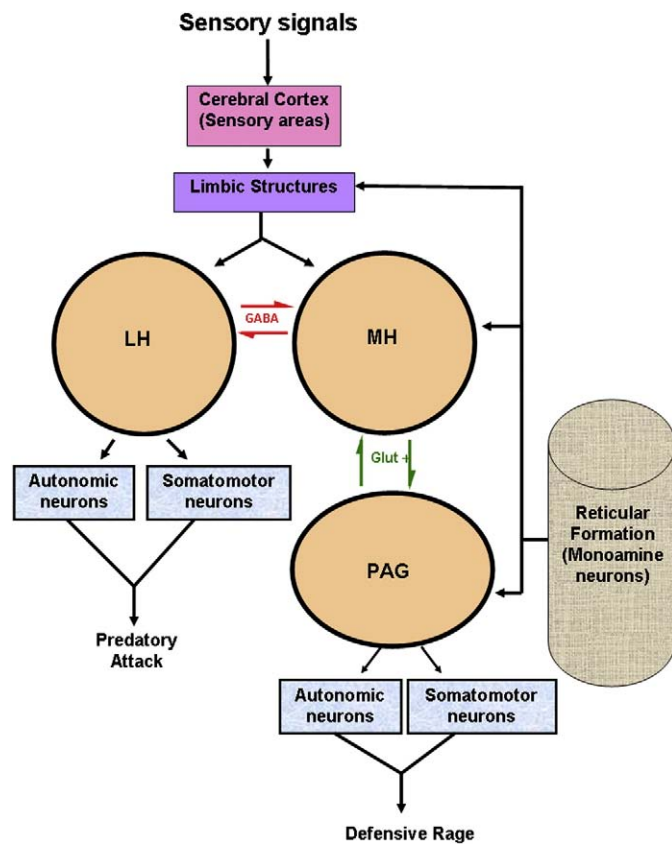


Fig. 1. Schematic diagram illustrating the relationships of the limbic system (and the key regions that regulate its activity) to the lateral hypothalamus (LH), medial hypothalamus (MH), and midbrain periaqueductal gray (PAG). The expression of predatory attack is mediated through LH and defensive rage through MH, and through its descending glutamatergic (glut) pathway to the PAG. Reciprocal inhibitory connections between LH and MH utilize GABA as a neurotransmitter. This relationship allows either predatory attack or defensive rage to occur at a given time; this takes place because when one of the responses is prepotent, the other is suppressed by virtue of the inhibitory relationship with the other region. The limbic system receives critical inputs from the cerebral cortex, especially sensory signals, which presumably provide such signals with affective (emotional) qualities, which then modulate functions of the hypothalamus and PAG. The limbic system, cerebral cortex, hypothalamus, and PAG also receive significant inputs from monoamine neurons of the brainstem, which serve as a powerful modulating function of these structures.

Table 1. From these studies and those determined from the animal literature, it may be concluded that that limbic system powerfully modulates functions of the hypothalamus and PAG in both animals and humans. Accordingly, damage or disruption of a limbic structure significantly disrupts the regulatory mechanisms modulating aggressive behaviors, resulting in loss of control over these functions.

5. Neurochemical correlates of aggression and rage

The neurochemistry of aggression and rage has been a major focus in the search for the mechanisms underlying limbic and hypothalamic control of these processes. Therefore, a brief summary of the basic findings are presented at this time of the studies conducted over the past four decades, which identified the different classes of neurotransmitters and their receptors that play a role in regulating aggressive behavior (reviewed in Siegel, 2005; Siegel et al., 1999). These include the following small molecule neurotransmitters: acetylcholine, GABA, and biogenic amines (dopamine, norepinephrine and serotonin), and neuropeptides such as opioid peptides, substance P, cholecystokinin and possibly nonapeptides including oxytocin and arginine vasopressin. Some of these transmitters potentiate aggressive responses while others have inhibitory properties.

Animal studies have shown that cholinergic agents generally facilitate aggressive responses. These findings are based upon the application of agonists and antagonists systemically that act through muscarinic receptors. Further studies supporting these findings have indicated that cholinergic agents produce their potentiating effects within the region of the medial hypothalamus and can, in fact, induce rage-like responses.

Both dopamine and norepinephrine have similar potentiating effects upon both defensive rage and predatory attack. The mechanism presumably involves activation of catecholaminergic neurons of the brainstem from such regions as the locus ceruleus for norepinephrine and the ventral tegmental area for dopamine, which project to widespread regions of the forebrain, including the hypothalamus and limbic system. Dopamine facilitation is mediated through dopamine D₂ and norepinephrine through α₂ receptors in the medial hypothalamus. Catecholaminergic facilitation of both defensive rage and predatory attack suggests that these neurotransmitters exert potentiating effects upon whatever ongoing responses are present during the epoch of time when these transmitters are activated. However, the role of dopamine is thought to be more *permissive* than *productive* of aggression. Serotonin is distributed from brainstem dorsal raphé neurons to the PAG, hypothalamus and limbic system. The main impact of this transmitter seems to be suppression of impulsive aggression. In contrast, activation of 5-hydroxytryptamine (serotonin) type-2 receptors (5-HT₂ receptors) in these regions facilitates defensive rage. The effects of serotonin are discussed further below.

Several pathways are associated with the expression or modulation of aggressive or rage behavior whose primary neurotransmitters have been identified. These include glutamate neurons projecting from the medial hypothalamus to the PAG that act through NMDA receptors to mediate the expression of defensive rage, and SP neurons in the medial amygdala that project to the medial hypothalamus, which powerfully facilitates defensive rage and suppresses predatory attack. Glutamate neurons that project from the basal amygdala to the PAG, acting through NMDA receptors, also facilitate defensive rage behavior. Several peptides have also been identified that potentiate defensive rage behavior within the PAG. These include substance P, acting through neurokinin₁ receptors, and cholecystokinin (CCK), acting through CCK_B receptors.

Three neurotransmitters – 5HT, opioids, and GABA – suppress defensive rage. Activation of 5-HT_{1A} receptors in either the PAG or medial hypothalamus by serotonin released from brainstem raphé neurons suppresses this form of aggressive behavior. Opioid peptides, when elevated, normally suppress aggressive behavior. Opioid withdrawal induces aggressive behavior; this phenomenon can be

Table 1

Violence in humans resulting from dysfunction of the temporal lobe and hypothalamus.

Author	Type of dysfunction	Behavioral manifestations	Comment
Serafinides (1965)	TLE (medial temporal sclerosis with tumors) ^a	Character disorders with aggressive outbursts	Reduction in aggression following temporal lobectomy
Malamud (1967)	Temporal lobe tumor	Marked increase in rage and violence with little provocation	Tumors in 9 patients displaying rage were located in temporal lobe
Ounsted (1969)	TLE	Hyperkinetic syndrome with rage outbursts	Positive correlation between age (early onset and occurrence of rage)
Sweet et al (1969)	Temporal lobe tumor	2 patients: 1 tried to kill his family; the other also physically attacked family members	Symptoms had disappeared after removal of tumor
Mark & Sweet (1974)	TLE	Violence induced with little provocation (i.e. patient stabbed stranger when he was accidentally bumped)	Amygdaloid lesion reduced rage behavior
Falconer (1973)	TLE	Inter-ictal aggression	7 of 12 patients improved after unilateral temporal lobectomy
Hermann et al (1980)	TLE	Psychopathic deviation and hypomania	Chronological age is inversely correlated with aggression scores
Hood et al (1983)	TLE involving amygdala and periamygdala cortex	Increased aggression and irritable behavior	Amygdalectomy markedly reduced rage behavior
Martinius (1983)	Temporal lobe tumor	Killed 16 people and wounded 32 before police shot him	Malignant tumor adjacent to lateral amygdala
Taylor (1983)	TLE	Epileptic episodes and behavioral problems	Benefits of temporal lobectomy
Vaernet (1983)	TLE	Hyperaggressive behavior	Temporal lobe resection reduced aggression
Alpers (1940)	Anterior hypothalamic tumor	Hyperaggressivity (patient flew into rage with little provocation)	Sudden onset of rage associated with development of tumor
Reeves & Plum (1969)	Tumor of ventro-medial hypothalamus	Person had low threshold for violent and aggressive behavior (hit and biting the examiner)	Behavior paralleled responses seen in the animals with lesions of medial hypothalamus (i.e. rage and obesity)
Berkovic et al (1988)	Hypothalamic hematoma	Uncontrolled violent rage lasting for hours (assaulted teacher and parents with a knife)	Author concluded that response paralleled that seen in animal models
Tonkonogy & Geller (1992)	Craniopharyngiomas with lesions of the medial hypothalamus	Intermittent explosive rage disorders	Hypothalamic lesions played major role in development of rage
Devinsky et al (1992)	Hypothalamic cholinergic receptor dysfunction	Violent responses with little provocation (i.e., multiple stabbing, killing and biting of victims)	Termination of exposure to cholinesterase inhibitor reduced violence
De Reuck (1983)	Cerebral infarct	Convulsive episodes	Convulsive disorder accompanying stroke temporal lobe herniation and brain stem compression
Gedye (1989)	Frontal lobe seizure	Involuntary aggression	Similarity with Tourette syndrome

Modified from Schubert and Siegel, 1994.

^a TLE = temporal lobe epilepsy.

understood in terms of the absence of critical levels of enkephalins in the central nervous system. Powerful suppression of defensive rage behavior is mediated through μ -opioid receptors in the PAG. These receptors are activated by enkephalinergic neurons arising in the central nucleus of amygdala. GABA_A receptors in the medial and lateral hypothalamus suppress defensive rage and predatory attack behaviors, respectively. GABA_A receptors in the medial hypothalamus are activated by GABA neurons projecting from the lateral hypothalamus, and likewise, GABA neurons arising in the medial hypothalamus activate these receptors in the lateral hypothalamus. GABA_A receptors in the PAG also suppress defensive rage behavior when activated by GABA neurons, the origin of which has not yet been identified.

6. Genetics and aggression

Multiple methods have been applied to the study of genetics in aggression and rage behavior. An older approach utilizes traditional breeding methods. A more recent approach involves the use of genetic engineering to produce "knockout" mice in which specific receptors are not expressed. With respect to the first approach, increased levels of aggression are present under the following conditions: (1) in animals selectively bred for heightened sensitivity to cholinergic agonists; (2) in animals bred in a manner producing higher levels of brain dopamine levels; and (3) in animals bred for selective loss of 5-HT axons. Thus, these findings have generally supported the findings obtained from pharmacological and neurochemical approaches summarized in the previous section of this chapter. Concerning the second approach, mutant mice lacking the 5-HT_{1B} receptor or which display decreased

5-HT turnover in the brain have increased levels of aggressive behavior, which is consistent with the findings from more classical pharmacological approaches to the study of aggression and rage. Increasingly, investigators are also able to insert genes that have been primed for controlled expression, meaning that the gene's transcription and translation can be switched on or off to test functional hypotheses. This approach is expected to yield a more nuanced understating of gene-environment interactions in aggression.

Human molecular genetic studies of aggression adopt a different strategy, searching for rare mutations or common *allelic polymorphisms* (gene variants) associated with atypical aggressive behavior. It has been shown, for instance, that several gene variants that lead to low-MAOA-expression also lead to aggressive and violent traits. The shorter allelic form of the promoter region of the 5-HT transporter gene is similarly linked to impulsivity and aggression.

7. Relationship of defensive rage and predatory attack to human aggression

7.1. Defensive rage behavior

Several authors have attempted to directly relate animal models of defensive rage and predatory attack to parallel forms of human aggression (Meloy, 1988; 1997; Vitiello, Behar, Hunt, Stoff & Riciutti, 1990). In general, greater amounts of attention have been given to behaviors linked to defensive rage. This presumably is the case because this form of aggression appears to be more common and that there is less difficulty in identifying it in humans than predatory aggression.

There are striking similarities between the characteristics of defensive rage in animals and in humans. For example, common to both animals and humans, defensive rage is associated with sudden, significant increases in sympathetic activation. The response is quite impulsive and clearly lacks cortical involvement (as shown from animal studies). In fact, and as noted above, this response remains intact in spite of ablation of the forebrain. A third feature of this response is that there is displacement of the target to other individuals in the environment (in contrast to predatory attack in which the target is highly specific). A fourth feature of this response is that it is basically aversive in nature, and therefore, the rage response is designed to reduce or eliminate the threat stimulus and thus reduce the tension present in the environment.

“Episodic dyscontrol,” which has been used to describe individuals with explosive personalities (Monroe, 1978), can perhaps be included within the domain of defensive rage behavior. According to Monroe, a basic characteristic of episodic dyscontrol is the lack of impulse control, especially in concert with the expression of anger and rage. This behavior is called “Intermittent Explosive Disorder” (IED) in the nomenclature of the *Association American Psychiatric* (2000). Primary features of this behavior include decreased impulse control – a characteristic common to defensive rage behavior – and altered perceptual states following stimuli evoking anger, fear or rage. The neural basis for episodic dyscontrol has been proposed to involve alteration of impulses from limbic structures such as the amygdala and prefrontal cortex to the hypothalamic and PAG neurons associated with the expression of defensive rage behavior. Yet the spontaneous and unprovoked nature of IED in humans does not match the usual model of defense in response to overt threat. The authors speculate that secondary emotions, for instance, those experienced based upon rumination, may activate the circuitry of defense in the absence of external threat.

7.2. Predatory attack behavior

Stalking and killing to obtain concentrated sources of protein is the essence of predatory behavior. Humans are omnivores; our diets are derived, in part, from protein obtained by killing other animals. But modern people relatively infrequently exhibit this form of food-seeking predation. It has nonetheless been proposed that certain types of human aggression are justifiably referred to as predatory. In this section we will briefly comment on several conceptualizations of human aggression that may be physiologically related to animal predation.

Meloy (1988, 1997) provided perhaps the clearest description of human predatory aggression. Several features of predatory aggression in humans parallel those described in the cat. For example, during predatory aggression, there is a relative absence of sympathetic activity, which is a highly prominent characteristic of defensive rage. A second feature is that there appears to be less awareness of emotion. The emotion or emotions associated with this behavior seem to have positive reinforcing properties such as heightened self-esteem and a greater sense of self-confidence, a feature that may have parallels in predation in animals. This contrasts directly with defensive rage, both in humans and animals, which is basically aversive in nature. A third feature of predatory attack in humans and in animals is that the behavior appears planned and purposeful. In subhuman animals, the behavior is almost always directed against an animal of another species, usually a typical prey object (such as a cat attacking a rat or mouse). However, predatory aggression in humans is usually directed against other human beings. The question may be asked: what is the function of predatory behavior in humans when food is readily available in stores and supermarkets? Meloy suggests that human predatory behavior may be used “to gratify certain vengeful or retributive fantasies. It may be subjectively experienced as a necessary behavior that would be clinically assessed as compulsive” (Meloy,

1988, p. 215). A fourth property common to both animals and humans is that there is little perceived threat. In contrast to defensive rage behavior in which the individual typically perceives a serious threat from a specific source, the aggressor's approach to his target might be considered a pragmatic form of stalking. A fifth characteristic of human predatory aggression is that it may be triggered by a variety of motivating factors such as drives for monetary gain, power, control, or gratification of sadistic desires and fantasies. This contrasts with defensive rage where there is typically a single objective, namely, a desire to reduce a perceived threat.

Additional characteristics of human predatory aggression have been identified by Meloy. For example, in contrast to defensive rage in which there is considerable displacement of aggression from one target to another, the individual displaying predatory aggression is highly focused upon a specific target. The predator is capable of filtering out other sensory information much the same way the cat does in focusing upon the prey object. Of interest is that the act of aggression may take place over minutes, hours, days, weeks, months, or even years, in which the attack response may be preceded by various rituals (e.g., wearing of certain items of clothing, uniforms, nationalistic and religious symbols, weapons, and masks). Moreover, these objects may acquire anthropomorphic properties in which the aggressor fantasizes control over them, which is then used as a basis for exerting control over the actual victim. What is equally significant here is that this process includes a cognitive component, especially when fantasy plays an important function. In contrast, defensive rage behavior does not require cortical involvement in order to be expressed, although the cerebral cortex may play a key role in controlling defensive rage and predatory aggression, alike (see discussion below).

In one of the few published studies emphasizing defensive (or affective) rage versus predatory attack in humans, Vitiello et al. (1990) applied these categories to the aggressive behavioral patterns of children. Their study employed 73 children and adolescents with histories of aggressive behavior. Utilizing a 10-item questionnaire in which five items were designed *a priori* to measure defensive rage and five items assessing predatory attack, it was reported that one group presented mainly with affective (defensive) aggression and the other group reflected a mixed affective-predatory pattern. Of interest, the group identified as affective had lower IQ scores, received neuroleptics or lithium, and were diagnosed as schizophrenic. The predatory group appeared to have a greater propensity for drug abuse than the affective group. That “predatory” children had characteristics of both predatory and affective aggression indicates the inherent difficulty in classifying humans with pure types of aggression. Future studies might better characterize the applicability of these ideal types of aggression to human behavior if they were to include a larger sample size, more refined assessments, and physiological measures.

7.3. Other approaches to the subtyping of aggression

A number of investigators have suggested alternative ways of conceptualizing subtypes of aggression. The “proactive-reactive” classification of aggression represents one such dichotomous classification scheme that has received attention. Reactive aggression reflects an angry, defensive response to some form of provocation or situation which generates frustration. Proactive aggression purportedly reflects a desire to achieve a desired goal and therefore constitutes a deliberate, directed, and focused form of aggression (Crick and Dodge, 1996). In their study, Crick and Dodge examined 624 9–12-year old who were classified either as proactive-aggressive, reactive-aggressive, mixed type, or non-aggressive. These authors observed that children with proactive aggression believed themselves to be more confident about conducting aggressive acts than their peers. In contrast, children with histories of reactive aggression would interpret the behavior of a peer as intentionally harmful to the self, in which case, aggression serves as retaliation against the peer. One may thus conclude that there are

striking similarities between reactive aggression and defensive rage and, likewise, between proactive and predatory aggression.

Another conceptual approach was suggested by Kingsbury et al. (1997) who introduced a different bimodal classification scheme – hostile vs. instrumental aggression. Instrumental aggression can be understood in terms of principles of operant (instrumental) conditioning. In this context, aggression occurs as a function of the expectancy of the anticipated reward. That reward may be material, as in murder for hire, or social, as in the reinforcement given by gangs and mobs to individuals engaged in behavior perceived to serve the group's values and needs. The instrumental aggressor may not possess any concept of guilt or other negative feelings associated with the act of aggression. It seems plausible that, at least to some degree, humans exhibiting instrumental offensive aggression recruit the same neural circuitry as carnivores involved in predation.

While an individual who exhibits instrumental aggression does harm to another person in order to achieve some form of reward, an individual who engages in hostile aggression does so with a conscious or unconscious drive to specifically harm another person. Hostile aggression may function to reduce a threat situation and is usually associated with heightened states of behavioral and physiological arousal.

Again, there are clear similarities between instrumental and hostile aggression and predatory and defensive aggression. The linkage between instrumental and predatory aggression is that, in both animals and humans, the behavior is planned, positively reinforcing, and not usually associated with high levels of autonomic arousal. Likewise, hostile aggression and defensive rage share several characteristics in that they are both usually activated in response to threat, both have an impulsive quality, both typically involve the display of marked sympathetic signs, and both are directed at producing harm to a specific target. Accordingly, one may argue that the conceptualizations of aggression described above may be absorbed under two overarching categories: a predatory/proactive/instrumental form and a defensive/reactive/hostile form.

8. Can we control our tendencies for aggression and rage?

Based upon the above discussion, one may raise the question of to what degree conditioning or other learning mechanisms may be called upon for the control of aggression and rage. Theoretically, since the activity of the prefrontal cortex is highly plastic, partly accessible to consciousness, and important for restraint of impulsive aggression, learning might reduce aggressivity. Indeed, learned restraint probably plays an important role in the normal moderation of toddler-era aggression. A conditioning process may occur involving the prefrontal cortex in which sensory and autonomic signals from elsewhere in the central nervous system reach the prefrontal cortex, causing activation of the neurons in this region, ultimately leading to suppression of the neurons mediating aggression and rage in the hypothalamus and PAG. In behavioral terms, this would mean that sensory and/or autonomic cues would reach a level of consciousness, thus triggering off a warning signal to the individual that then reaches expression through activation of the prefrontal cortex. These warning cues or signals may be generated in a number of ways such as increased heart rate and blood pressure or a memory of the aversive aspects of anger.

The problem is that (a) individuals seem to exhibit innate, genetically determined variability in the extent of prefrontal emotional regulation and that (b) plasticity declines with age. For these reasons, one must have modest expectations for learned control of aggression after the developmental period. Some evidence supports cognitive behavior therapy and other talk-therapy interventions to reduce aggression among subgroups of motivated patients. So-called "anger management," a poorly defined class of treatments often administered by non-professionals, has not been shown to be efficacious.

9. Conclusions

The objective of this paper is to review and summarize the basic findings concerning the nature of the neurobiological and behavioral characteristics of aggression and rage. The main thesis of this review is that classifying aggression into two ideal types – defensive rage (affective defense) and predatory attack – represents a useful heuristic approach toward understanding both the behavioral properties of aggression in animals and in humans as well as the underlying neural substrates and mechanisms of these forms of aggression. In both animals and in humans, defensive rage behavior contains the following basic features: it is activated by a threatening stimulus (which may include a self-generated emotions); it is associated with marked sympathetic output; it is impulsive; it does not require cortical involvement for its expression; and the attack response may be directed at a variety of targets (or individuals with respect to human aggression) present within the visual field. In contrast, predatory attack behavior involves the following characteristics: it is usually well planned, taking minutes, hours, days, weeks, months, or even years (with respect to humans) for it to occur; it is directed at a specific target; it reflects few outward sympathetic signs; and it generally requires cortical involvement for its expression. With respect to the neural bases for these responses, predatory attack requires activation of the lateral hypothalamus, while defensive rage requires activation of the medial hypothalamus and midbrain PAG. Both forms of aggressive behavior are controlled by different regions of the limbic system, which in turn, are influenced by sensory inputs from the cerebral cortex and monoaminergic inputs from the brainstem reticular formation. To different degrees at different ages and in different individuals, the modulation and control of aggressive tendencies can be controlled through conditioning and related learning principles engaging the massive human cerebral cortex.

Modern law is gradually developing a refined appreciation of the implications of these scientific observations. While triers of fact may not think in neurobiological terminology, there is an instinctive understanding of the difference between planned and unplanned aggression. In many jurisdictions, a perpetrator is held less criminally responsible if his act seems to have been primarily generated by the largely unconscious subcortical defensive rage system and more culpable his act seems to have been generated by consciously accessible cortical decision-making. The challenge for the future is not only to improve the neurobehavioral understanding of different types of aggression but to make the general public – who will become the jury – familiar with the basic tenets of behavioral neurology. All behavior is generated by the material brain. Dysfunction of that material interferes with normal perception of the environment, including threat, and undermines self-control. A large number of conditions, entirely beyond a person's control, can degrade the suite of cerebral functions necessary to comport one's behavior with society's expectations. Although titration of justice will forever be a function of social instincts rather than scientific algorithms, judges and juries who are well educated regarding these basic principles will be better able to reach judicious conclusions regarding moral responsibility.

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