

Neural Correlates of Violent Behavior: The Role of Anger and Other Psychiatric Disorders as Measured by Electroenceelography

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There is common agreement among neuropsychologists that anger is an approach-related negative emotion [1] that is usually associated with the attempt to counter the challenges to our wellbeing [2]. Occasionally, anger may result into favorable outcomes (compliance and co-operation) [3], which allows us to gain greater control over a situation of concern [4] and there is evidence that people who experience anger regularly rarely engage in aggressive, antisocial behavior [5, 6]. Hence, **anger is usually considered as a basic, necessary emotion** which may not necessarily lead to troublesome social consequences, if appropriately regulated. However, anger can significantly contribute to trigger aggressive behavior when its intensity is particularly high, which overrides coping mechanisms [7, 8].

Uncontrolled anger can lead to confrontational actions that may result in verbal or/and physical offence [9]. Moreover, anger can become particularly problematic when it becomes the main and most frequent emotion to drive behavior in response to frustration [10, 11]. For instance, persons with high trait anger often have **poor social relationships** [12] and are more likely to engage in **confrontation** [13], **aggressive behavior** [14, 15] and **domestic violence** [16]. Given the negative effects that chronic and persistent anger can have on an individual's life, including the risk of being punished by society [17], people are usually motivated to regulate and control anger states [18].

Inhibitory control has been proposed as one of the main factors behind inter-individual differences in trait anger and aggressive behavior [19, 20]. In particular, the **integrative cognitive model of trait anger and reactive aggression** [19, 20] proposes that **effortful control** is a psychological process that allows mitigating the escalation of anger and reactive aggression by:

1. Promoting reappraisal in favor of a non-hostile framework
2. Allowing individuals to disengage from rumination
3. Blocking angry communication and aggressive behavior

Importantly, the model proposes that effortful control can be considered as a **resource that can be recruited in specific contexts**, so that individuals with lower anger trait are capable to activate effortful control resources in potentially anger-provoking situations in order to “keep their cool”, until a more reasonable, non-confrontational solution comes to mind.

In line with proof evidence highlighting the **poorer prefrontal top-down control over limbic and subcortical regions** exhibited by aggressive individuals [21-23], the lateral and medial prefrontal cortex are the brain regions that have been proposed to be involved in top-down emotion regulation and inhibitory control, [24, 25].



Employing electroencephalogram to detect higher risk of violent behavior

Research employing electroencephalography (EEG) suggests that high trait anger persons exhibit reduced attentional control, diminished behavioral inhibition and **lower relative left frontal activity** during performance of tasks that require effortful control [26]. A similar pattern has been observed in depressed patients exposed to anger provoking stimuli [27], although the differential role of anger in the EEG anomalies detected in this instance still needs to be determined.

Also, research employing **event related potentials (ERP)** found that faster reaction times and a decreased amplitude in the **N200 and P300** response to emotionally challenging stimuli can be found in high trait anger individuals when compared to low trait anger individuals, which confirms an impaired response inhibition in this population [28, 29]. Notably, although high trait anger is most often associated with violent behavior [10], there is also evidence that some violent offenders may show an ‘over-control’ of anger whereas others may be better characterized by under-controlled anger [30]. In this regard, it has been proposed that the reduced amplitude of the components N200 and P300 might reflect the degree of impulsive aggressive behaviors exhibited by violent offenders and not the intensity of anger. This suggests that these two ERP components might have an important **diagnostic role in the treatment of dysfunctional anger**, predicting treatment efficacy, relapse and dropout from anger management programs. In this regard, studies have also shown that **training aiming at enhancing cognitive control**, may be effective in reducing anger or aggression [31].

Beyond anger: Detecting and treating EEG anomalies associated with criminal offending

Criminal offenders are a unique patient group when it comes to devising interventions aimed at reducing violent behavior. This population sample often exhibits externalizing behavior, may suffer from schizophrenia, attention-deficit hyperactivity disorder (ADHD), substance-use disorder (SUD), and cluster B personality disorders [32, 33].

While it can be extremely challenging to treat symptoms of each of these conditions separately, there is evidence that EEG-based interventions such as **neurofeedback training** could be more effective at reaching a positive clinical outcome. In particular, there is evidence that, after treatment with neurofeedback, improvements were found in criminal offenders in multiple domains, including impulsivity [34-36], psychopathy [37], hostility [38], and drug use [38, 39].

In other cases, while neurofeedback training might not be effective at normalizing all the EEG deviations exhibited by criminal offenders, it could play a role in reducing secondary factors such as treatment retention and risk for recidivism by lowering the levels of impulsivity (often higher in ADHD and/or SUD) [40, 41]. Furthermore, studies have shown that neurofeedback training (especially alpha-theta protocols) **improve mentalization** [42, 43], which in criminal offenders could lower aggression rates [42].

Conclusions

While anger is a necessary emotion to protect the individual from unfavorable situations, it can become particularly problematic when it becomes the dominant emotion in response to life challenges.

Individuals with high trait anger display EEG anomalies that overall reflect greater impulsivity and reduced effortful (cognitive) control. In this regard, research suggests that anger management programs should aim at enhancing effortful control rather than reducing anger.

Finally, in criminal offenders, multiple psychiatric imbalances coexist and interact to generate a complex EEG profile. EEG-based interventions are more likely to produce a positive clinical outcome when implemented against a normative template.

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