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Usability of MAO-A gene in the judicial process

Ulviyya Mustafayeva[1], Burcin Yuksel[1], Ozlem Akkan[2]

[1]İstanbul University-Cerrahpaşa Institute of Forensic Sciences and Legal Medicine, Department of Science, İstanbul, Türkiye
[2]Iğdır University, Faculty of Agriculture, Department of Field Crops, Iğdır, Türkiye

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Abstract

Monoamine oxidase (MAO-A) is an enzyme found in the nervous system and plays an important role in the breakdown of monoamine neurotransmitters. This enzyme varies among individuals depending on genetic factors. The monoamine oxidase-A (MAO-A) gene has been studied by various researchers to understand behavioral differences between individuals and evaluate crime propensity. However, serious ethical and legal problems may arise regarding the use of genetic factors alone in the judicial process. In this context, considering environmental factors as well as the MAO-A gene may contribute to the development of a more comprehensive approach. The role of the MAO-A gene in the judgment process has created an area of research that allows us to understand behavioral differences. The MAO-A gene has been associated with various behavioral traits. It has particular effects on aggressive behavior, antisocial behavior, and emotional reactions. In this context, the MAO-A gene may be an important factor in determining how individuals respond to environmental factors and guide their judgment processes. Some studies show that individuals with low MAO-A activity may be prone to antisocial behavior and crime. Thus, the MAO-A gene can be taken into consideration in determining guilt in legal processes. Assessing individuals' criminal propensity based on genetic factors can make the justice system more effective and fair. For example, harsh childhood conditions or traumatic experiences can trigger genetic predispositions and increase criminal propensity. In this case, it is important to take environmental factors into account when evaluating the genetic profile of the individual during the judicial process. Many ethical and legal issues need to be carefully considered on how to integrate the MAO-A gene into the judicial system. Therefore, research on the usability of the MAO-A gene in the judicial process should be continued.

Keywords: Monoamine oxidase, forensic genetic, case study, heredity and crime, serial killer

Introduction

Monoamine oxidase (MAO-A) genetics

The MAO-A gene encodes an enzyme called Monoamine oxidase (E.C. 1.4.3.4), which is vital for the breakdown of neurotransmitters such as serotonin [1]. Monoamine oxidase breaks down neurotransmitters such as noradrenaline, adrenaline, serotonin, and dopamine and therefore plays an important role in regulating mood. It increases the individual's susceptibility to antisocial traits or risk factors for antisocial behavior (such as low self-control or impulsivity and negative emotionality) through its effect on the serotonergic system. For this reason, this variant of the MAO-A gene is sometimes called the "warrior gene" or "violence gene" [2]. The MAO-A gene is located on the X chromosome. Since women have two X chromosomes, they can be heterozygous or homozygous. Males, on the other hand, carry only one copy (as they have one X and one Y sex chromosome) and are therefore homozygous. The MAO-A gene regulates neurotransmitters such as serotonin and dopamine from the prenatal period throughout life [3]. Considering that males (XY) have only one X chromosome while females (XX) have two X chromosomes, females carry two versions of the same gene on each of their X chromosomes. Therefore, men are more vulnerable than women to any abnormality carried on this chromosome. Because in men, there is no second version that can alleviate the effect of the affected gene or increase its functionality or efficiency. This is why the link between double-repeat variants of the MAO-A gene and impulsive-reactive aggression is found only in men, not in women. Men

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Corresponding Author: Ulviyya Mustafayeva, 1İstanbul University-Cerrahpaşa Institute of Forensic Sciences and Legal Medicine, Department of Science, İstanbul, Türkiye
Email: ulviyyamustafayeva11@gmail.com

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are three times more likely to have this genotype than women (37% vs 12%) [2]. Changes in MAOA activities are not related to SNPs (Single Nucleotide Polymorphism) within individuals; It is mostly due to changes in the promoter region [4]. Within the promoter region of MAO-A is a region of DNA known as a variable number of tandem repeats, or VNTR (Variable Number of Tandem Repeats). VNTRs occur as 2R (two-repeat sequence) or 3R (three-repeat sequence) in the MAO-A gene. This is important because the number of repeats has a big impact on how well MAO-A is "read" by the polymerase enzyme. When the gene is not read efficiently, as much MAO-A is not produced, meaning the breakdown of neurotransmitters is reduced. It is thought that the factor that causes MAO-A gene variants to increase aggressive behavior is the lack of MAO-A enzyme activity. The 3.5R and 4R variants are considered normal, with the 2R variants having the most reduced function and the 3R and 5R variants falling in between. For this reason, types 2R, 3R, and 5R are sometimes referred to as MAO-A-L, meaning low activity [5]. However, it has also been recognized as an important factor in the clinical course of other mental disorders, including anxiety and depression, in women [6,2]. Although MAO-A-L forms are known to be associated with increased aggression, it does not mean that someone with the MAO-L form will be aggressive. The most important of these are environmental factors.

Heredity and crime

The issue of heredity and crime underwent a controversial evolution under the influence of the eugenics movement between the late 19th and early 20th centuries. The eugenics movement advocated the selective breeding of individuals based on genetic characteristics and the sterilization of those with undesirable characteristics, including criminals. This approach is based on the idea that criminal behavior is inherited and can be eliminated through selective breeding. The eugenics movement became widely accepted in the United States and Europe and developed policy and social science insights based on these principles. This influence was reflected in studies of heredity and crime throughout the 20th century. Today, however, the study of heredity and crime has moved beyond the simplistic and discriminatory views of the eugenics movement. Researchers have understood the complex interplay between genetic and environmental factors and have drawn attention to social and economic inequality in addressing criminal behavior [5]. Heredity refers to the genetic transmission of individuals' phenotype and genotype characteristics from one generation to the next. This process plays an important role in determining the individual's physical and behavioral characteristics, including criminal behavior. The concept of heredity and crime involves the study of the relationship between genetic factors and criminal behavior. Some research has suggested that certain genetic variations may increase the risk of criminal behavior, but it is important to emphasize that genetic factors alone are insufficient to determine criminal behavior. In childhood, environmental factors such as poverty and socialization are also important factors that affect an individual's tendency toward criminal behavior. Understanding the interaction between genetic and environmental factors is critical to fully understanding criminal behavior. It is important to note that while genetic factors can increase an individual's vulnerability to criminal behavior, environmental factors can reduce or worsen genetic predispositions. For example, a person with a genetically aggressive predisposition may not exhibit criminal behavior if raised in a supportive and healthy environment. On the other hand, a person who does not have a genetically aggressive predisposition may exhibit criminal behavior due to stress, trauma, or abuse experienced during childhood [5].

Case study: Inside the mind of a serial killer: Ted Bundy

The life of Ted Bundy is an example of a study that explains the interaction of genetic predisposition and childhood trauma. Bundy is a serial killer who was convicted of raping and murdering 36 young women in the 1970s. He has a complicated family history due to illegitimate birth. He has known his real mother as his older sister for years. This situation led Bundy to commit minor crimes and develop a sense of untrustworthiness. The period in which Bundy experienced psychological trauma dates back to the relationship problems he experienced in college. When his relationship with a friend named Stephanie Brooks ended, Bundy experienced psychological trauma and had to drop out of college. From this point on, he began raping and murdering young women who looked like Brooks. Bundy's clever and planned murder caused him to leave no trace and not be caught by the authorities. However, being caught for theft in Utah did not put an end to his murders. After years spent defending his innocence in court, Bundy was sentenced to death for his crimes [5]. The tragedy in Ted Bundy's life shows that childhood trauma, as well as genetic factors, are effective. However, attributing Bundy's actions solely to a genetic predisposition is insufficient. Bundy's defense attorney, Polly Nelson, emphasizes that Bundy's emotional trauma over trusting or distrusting parental figures was a determining factor influencing his terrible choices. The lack of the MAO-A gene alone cannot cause Ted Bundy or anyone with the same genetic characteristics to become a serial killer. The important thing is to understand the interaction of genetic and environmental factors [6].

Case study: Yepez case

The 2012 case between Anthony Blas Yepez and his girlfriend Jeannie Sandoval focused on the admissibility of genetic evidence in court proceedings. Sandoval lives with her stepmother's 75-year-old boyfriend, George Ortiz. As a result of an argument with Ortiz, Yepez killed him, dipped the body in oil, and set it on fire. Yepez and Sandoval then took the victim's car keys and went to drink alcohol. He was later caught and arrested in New Mexico for premeditated murder. The evidence convicting Yepez was strong, so he sought to reduce the involuntary manslaughter charge to a lesser offense. The defense argued that Yepez had low activity in the MAO-A gene and that this genetic trait, combined

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with childhood maltreatment, predisposed him to "violent behavior." To support this claim, Yepez presented at the hearing the testimony of a forensic neuropsychologist and two academic psychologists presented expert testimony regarding the MAO-A gene. Two scientific studies were discussed in detail to support Yepez's defense. The first study was by Brunner et al. in 1993, in which a complete lack of MAO-A activity, known as "Brunner syndrome", was associated with impulsive aggressive behavior. The second study found that childhood maltreatment combined with low levels of MAO-A activity was associated with antisocial behavior. However, the court ruled that the genetic findings did not meet the standards required for a mental disorder that would not preclude Yepez from intending to commit premeditated murder and that the expert testimony did not match the scientific evidence. The court noted that the studies examined mostly "impulsive" actions and did not support the alleged relationship between the reduced activity of Yepez's MAO-A gene and increased impulsivity. Yepez appealed his conviction, arguing that he failed to consider MAO-A evidence in court, and claimed that his case was now relevant to the premeditated manslaughter charge. The appellate court stated that jurors should consider expert testimony regarding the MAO-A evidence, but the high court unanimously ruled that it was within the court's discretion not to include the MAO-A evidence. The court concluded that "the mere showing of genetic predisposition as the cause of a certain mental state is not related to the defendant's intentional behavior" [7].

Literature Studies

In an article published in 1993, Dutch geneticist Han Brunner and his colleagues identified a possible connection with the MAO-A-L variant, which is considered a risk factor for violence and aggression. Brunner's team studied a Dutch family seeking genetic counseling whose male members in particular exhibited a behavioral pattern prone to excessive and persistent reactive aggression. Brunner and his team studied the MAO-A gene, which encodes an enzyme that plays a role in regulating aggression in animals and humans. The study, conducted on a cohort of more than 1000 people and followed between the ages of 3 and 26, revealed that not every individual with low MAO-A activity is prone to violence. A tendency towards violence was observed only in the group that was exposed to maltreatment and abuse during childhood. A case of the MAO-A gene has also been identified, represented by 0-rp alleles, which were determined to have a rare mutation in the MAO-A gene, thus creating a functionally blocked gene. This, as well as the case of fully functionally blocked MAO-A, has demonstrated a link between serotonin dysregulation due to low-potency MAO-A (or MAO-A-L; 2 or 3-rps) and impulsivity/reactive aggression, a type of antisocial behavior. They emphasized that this study is a study that contributes to the issue that variants of a gene can be affected by an individual's environmental experiences as well as their genetic characteristics.

A study published in 2014 was conducted on prisoners in Finland and suggested that the MAO-A and CDH13 genes may be associated with extremely violent behavior. This study suggested that at least 5-10% of all violent crimes in Finland can be attributed to MAOA and CDH13 genotypes. Additionally, a study published in the Journal of Police and Criminal Psychology in 2005 showed that 26% of serial killers were sexually abused as children, 36% were physically abused, and 50% were psychologically abused. These data demonstrate that childhood trauma is linked to serial killer behavior [8]. There are many studies on this in the literature [9-11].

While different meta-analysis studies have shown an association between the MAO-A-L allele and aggression, violent behavior, and antisocial behavior, the MAO-A-H allele is low risk. First, a meta-analysis of five independent studies (approximately 2570 men) reported that childhood adversities (domestic violence, parental neglect, physical or sexual abuse, harsh discipline, etc.) were associated with antisocial behavior among carriers of the male MAO-A-L genotype [9]. A subsequent meta-analysis of 31 studies confirmed MAO-A-L as a risk allele for aggressive and antisocial behavior [10]. Finally, a more recent and expanded meta-analysis study investigated the impact of the interaction between childhood adversity and MAO-A genotype on the emergence of aggressive antisocial behavior at later ages in both men and women. These studies were mostly conducted in non-clinical individuals. First, a meta-analysis of 20 studies consisting of all-male or male-female samples (11,064 participants) found that MAO-A-L carriers of men who were exposed to maltreatment and other adversities in childhood had higher levels of aggression/violence in childhood/adolescence as well as in adulthood. revealed that he exhibited aggressive/violent antisocial behavior as well as non-violent antisocial behavior [11]. According to the most comprehensive studies on the MAO-A gene, the frequency of the 3R variant is estimated to be around 51–59% in African Americans and 33–37% in Caucasians [12-14]. On the other hand, the 4R allele is found in 36-43% of African Americans and 60-65% of Caucasians. Frequency data for other ethnicities, such as Asians, non-white Hispanics, and Pacific Islanders, are still unclear, because estimates for these populations are often based on small groups.

There are studies in the literature showing that the MAO-A gene may be race-specific. Several studies have revealed that the effects of this gene-environment interaction may be race-specific. A study of 600 participants with a documented history of abuse and neglect before age 12 and followed into adulthood confirmed that the interaction between MAO-A-L variants and child maltreatment increased the risk of violence and antisocial disorders only in Caucasians. However, this is not the case for participants in other ethnic groups [12]. Similar racial differences have been identified in other studies [13]. These differences may result from both genetic and environmental factors. The frequency of MAO-A-L and MAO-A-H variants varies significantly among different ethnic groups. Additionally, other biological variables that may play a role in aggression, such as testosterone and other

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sex hormones, have demonstrated racial differences [9].

In studies arguing that the MAO-A gene is related to gender; There are several examples of how it leads to the development of antisocial personality disorder (ASD) in women. Some data suggest that MAO-A-L variants are associated with conduct-disordered behaviors in women. For example, in a study of Native American women, the MAO-A-L genotype was observed to be more common among individuals with ASD. Additionally, MAO-A-L homozygous women with a history of childhood sexual abuse are more likely to show ASD symptoms. This interaction has only been reported in women who were sexually abused in childhood [10,14,15].

In a study involving 482 subjects from Punjab city, the 3.5R variant in males and the 4R variant in females were found to have the highest frequency in the promoter region of VNTRs. Additionally, the genotype frequencies of a functional SNP (T941G, dbSNP ID: rs6323SNP) within this gene were GG=16.3%, TG=20.6%, and TT=63.1% in cases, while GG=12.7% in controls, TG=6.3% and TT=81.0%; these genetic variations show a significant association with aggression [1]. In a study conducted to determine the life stories of serial killers, the effect of early childhood abuse on serial murder types and murder behaviors was examined using Behavior Sequence Analysis. Data from 233 male serial killers who were subjected to physical, sexual, or psychological abuse were analyzed according to typologies and crime scene behavior [16]. As emphasized by previous studies in the literature, it has been observed that individuals who were sexually abused in childhood tend to gravitate toward sexual typologies. Although those who were physically abused had a higher tendency to "overkill" their victims, more specifically violent killing methods were used, especially by those who were sexually or psychologically abused. These examples include behaviors such as mutilating, torturing, and tying the victim [15].

In an article describing two cases of violent crimes committed by young carriers of genetic variants associated with personality disorders; In the first case, a young man was killed by a person who consumed alcohol and cocaine. The murderer attributed his tendency to commit crime to his childhood, citing genetic factors as justification for his predisposition to crime. The defendant was requested to conduct research on MAO-A, SLC6A4, and COMT genes by his forensic consultant and it was determined that he carried COMT polymorphism. In the second case, a 25-year-old man kidnapped and raped two women within 6 months while under the influence of alcohol. The court consulted a forensic psychiatrist to evaluate the defendant's criminal liability who was diagnosed with antisocial personality disorder. Additionally, it was determined that the defendant had a 3-repeat VNTR variant in the MAO-A gene [16]. A study conducted in Finland revealed that the low-activity MAO-A genotype and the CDH13 gene were associated with extremely violent behavior. No significant signals related to these genes were observed in nonviolent offenders. The study shows that these genes cannot be directly attributed to substance abuse and antisocial personality disorder but may be associated with violent crime. It has been determined that 5-10% of serious violent crimes in Finland can be attributed to MAO-A and CDH13 genotypes. In a meta-analysis involving 11,000 people, a significant interaction was detected between the low-activity MAO-A genotype and childhood adversities on later antisocial personality disorders. In the study, the low-activity MAO-A genotype was associated with the criminal group as a result of candidate gene analysis conducted on a total of 794 prisoners who committed violent and non-violent crimes in 19 prisons in Finland [16].

According to family, twin, and candidate gene studies examining the hereditary components of narcissism, psychopathy, and Machiavellianism, many studies are showing a relationship between MAO-A gene mutation and aggression. It has been reported that there is a negative relationship between sensation seeking and impulsivity, which are the defining features of psychopathy, and the MAO-A gene, and that low MAO-A gene activity is associated with psychopathy and aggression. Additionally, in men with low MAO-A gene activity, negative life events predict the development of psychopathy; In women, it has been reported that among those with high MAO-A gene activity, psychopathic behaviors are predicted only in those who have been maltreated [17].

In another study, VNTR polymorphism in the promoter region of the MAO-A gene, which plays an important role in the metabolism of catecholamines, was examined in male and female individuals. No change was observed with this polymorphism in the catecholamine concentration in the cerebrospinal fluid in women. Catecholamines, such as adrenaline, noradrenaline, and dopamine, serve as neurotransmitters in the central and peripheral nervous systems. The MAO-A gene is responsible for the catabolism of catecholamines. This polymorphism is effective in suicide, panic disorder, and antisocial behavior in female individuals. It has been determined that the VNTR polymorphism of the MAO-A gene is closely associated with gender-related anxiety and psychopathological disorders in healthy male and female individuals. Catecholamines are released during the stress response and therefore MAO-A gene polymorphism can be used as a discriminatory feature in predicting the cause of death in autopsy cases. Since the subjects are likely to be under great stress before or after death, it has been determined that many environmental factors, as well as the MAO-A gene polymorphism, can affect the concentration of catecholamines in the cerebrospinal fluid [18].

In a study conducted on white and black men, examining the effect of genotypes associated with high MAO-A levels on childhood maltreatment and antisocial behavior disorder, a sample group was used in which individuals who were abused in childhood were identified and observed until adulthood. The results of the study show that genotypes with high MAO-A activity protect violent tendencies in abused individuals later in life. However, no significant evidence of this protection was found in black men. Looking at other studies, observations in

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Caucasian boys in New Zealand provided the first evidence that functional polymorphism in the MAO-A genotype attenuates the effects of early childhood maltreatment [12].

In a study examining 11 criminal cases between 1995 and 2016, the majority of cases were from the United States and Italy. In 8 of these cases, the MAO-A-L genotypes of the defendants were detected, and it was stated that this genotype was presented as a defense against the crime of first-degree murder in two cases [7], [19]. However, the study has some limitations; Due to limited access to court documents, published opinions and summaries from standard legal databases were used as literature. Although the findings regarding the MAO-A-L genotype did not support a defense that would exempt the defendants from criminal liability, they were found acceptable for mitigating fault in criminal cases. Although the use of evidence in the field of behavioral genetics is increasing, results supported by experimental data indicate that the genetic risk of individuals with MAO-A-L genotypes may have a limited impact on punishment for aggressive and antisocial behavior [20]. Only in one case is there conclusive evidence that the MAO-A-L genotype was acceptable to a judge at the guilt stage [19]. Additionally, using this evidence the defense was successful in persuading the jury to apportion blame at a lower level.

Labonte and colleagues identified MAALIN, a long non-coding RNA (lncRNA) that regulates the activity of the MAO-A gene in the human brain. They revealed that epigenetic mechanisms regulating MAALIN expression in different brain regions are associated with MAO-A expression in suicidal impulsive-aggressive individuals. In addition to these findings, the authors found that overexpression of MAALIN in neuro progenitor cells in mice reduced MAO-A levels, whereas knocking out its expression caused elevation of MAO-A, and hippocampal MAALIN reduced MAO-A expression, which in turn exacerbated impulsive-aggressive behavior have shown [19,20].

MAO-A gene and criminal liability from a legal perspective

The use of neuroscientific evidence in criminal cases has increased worldwide over the last two decades. This evidence often includes neuroimaging, electroencephalography (EEG), and neuropsychological assessment [1,2]. It is important to determine the effects of the MAO-A-L genotype on criminal law and the general legal system. Legal and law enforcement officials need to understand that criminal behavior is a complex phenomenon influenced by both genetic predisposition and the environment. The genetic etiology of criminal behavior and the impact it can have been increasingly being embraced by academics, lawyers, judges, police officers, and legislators in the legal system. However, most experts remain skeptical [3]. Despite this controversy, as far as we know, there have been two convictions in Europe, in Italy [4] and in America [5]. In the decision, they did not accept the MAO-A profile as evidence but used it to support the mitigation of criminal liability [6]. Although there is some consistent information regarding the link between this gene and behavior, there are still gaps that need to be investigated. One of these concerns is how genetic information can affect criminal liability and how sentencing provisions can vary depending on the mental state of offenders. In particular, under Spanish criminal law, when an offender shows deterioration in his mental state, three different consequences can occur. A situation where the defendant is completely irresponsible regarding the crime: The defendant is considered an irrational perpetrator at the time of the crime; in which case he cannot be held responsible and may be sent to a psychiatric clinic. State of partial or incomplete mental retardation: If the offender's responsibility is significantly diminished, he or she may generally be subject to a commuted sentence. Case of some impairment in cognitive or control abilities: In this case, the sentence may be commuted and the issue of associating certain genetic factors, such as the MAO-A-L genotype, with criminality may be raised [6]. The MAO-A-L genotype has been associated with aggressive reactive impulsivity and may influence sentencing in cases of delinquency. However, there is no consensus on the inclusion of evidence regarding the MAO-A-L genotype in criminal proceedings [7].

Many studies are highlighting the importance of behavioral genetics in criminal cases. Behavioral genetics expert testimony is especially needed in US criminal courts. Generally, the criminal system has focused on allegations of genetic predisposition in terms of drug addictions. Allegations in US criminal cases have established that a single chromosome abnormality (XXY) or mutation in a single gene (MAO-A gene) causes violent criminal behavior. Research conducted in New Zealand in 2002 published an article on the interaction of genes and environment, showing that an individual's susceptibility to crime in later ages increases with this interaction [3]. The 1994 criminal case of Stephan A. Mobley is the only case reported in the USA that references MAO-A genotyping before the Caspy et al studies of 2002 and 2003 [19]. In the study, Mobley suggested that there may be a genetic basis for his violent nature and requested that his family be investigated, but this request was rejected. In studies conducted on the MAO-A gene, Armstrong and his colleagues found a connection between the MAO-A-L genotype and criminal behavior [3]. Fergusson et al. reported that criminal behavior in MAO-A-L carriers is associated with low IQ and familial factors such as maternal smoking during pregnancy and childhood maltreatment [2]. When the impact of scientific evidence on the decisions of the courts regarding the death penalty, the role of genetic factors, and the developments in the light of case studies are examined, it is seen that genetic information in the judicial system is still a controversial issue.

One example of courts reversing the death penalty comes from the case of Delgado v. State (2015). In this Florida case, the defense of Delgado, who was accused of murdering a police officer, argued that he had a genetic psychiatric disease that was beyond his control. The jury voted 8 to 4 in favor of the death penalty, but on appeal the death sentence was annulled, emphasizing

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the disproportion between crime and punishment. Similarly, an Italian appeals court reduced the sentence of a convicted murderer by one year in 2009 because he had a variation of the MAO-A gene, which is linked to aggression and violence, in another example of the influence of genetic factors on sentence reductions. However, it has been predicted that some courts in the USA accept genetic factors as evidence, which has the potential to lead to higher penalties, especially because individuals with certain alleles cannot be cured and may pose a risk to society for a longer period. This situation brings with it ethical and legal concerns about how genetic information will be used in the judicial process. Decisions regarding the role of genetic factors in the judicial process should be carefully examined in terms of fair trial, ethical evaluation, and legal norms [5].

Gene and environment interaction

Criminologists have argued that the environment rather than biosocial factors play a more influential and pervasive role in examining criminal mentality. According to this view, living conditions, social pressures, and political factors affect the individual's growth process and the way he psychologically adapts to his environment [7]. The impact of environmental factors on our brain and body is associated with the concept of “brain plasticity” and “epigenetic” modifications and can cause changes in phenotype throughout life [8-10]. If the interaction of gene and the environment is responsible for determining our phenotype by influencing the expression of our genes and the environment is constantly changing, it is thought that this interaction may also include the presence of genetic influence on behavior. This may offer new opportunities for treatment and rehabilitation by investigating the genetic origins of behavioral changes [6].

Studies on gene-environment interactions have shown that the MAO-A-L genotype can cause aggressive behavior in men exposed to traumatic life events. In particular, the MAO-A-L genotype has been associated with higher levels of delinquency in males who experienced parental separation or domestic violence in the first 15 years of life, and this genotype has been linked to aggressive behavior in adolescent males [11]. On the other hand, MAO-A-L has been proven to be a risk allele for violent behavior in psychiatric patients, independent of childhood trauma [9]. Brain MAO-A activity in humans affects the expression of the gene by methylating or not 14 CpG sites in the promoter region of the MAO-A gene [10]. In addition, many molecular genetic studies have shown that candidate genes such as serotonin transporter receptor (SERT), tryptophan hydroxylase (TPH), some serotonin receptors (5HT1A, 5HT1B, 5HT2A), MAO-A, COMT, and tyrosine hydroxylase (TH) are linked to personality traits such as impulsivity and aggression. It suggests that they may also play a role in the formation of suicidal behavior and cause suicidal behavior. Environment and social factors are as important as genetics in determining criminal behavior and are effective in shaping the behavior of criminals [21].

Single Nucleotide Polymorphism and MAO-A gene relationship

The impact of SNPs in the MAO-A gene on genetic and behavioral traits is important for understanding genetic diversity. These polymorphisms cause genetic differences between individuals through changes in enzyme activity. Studies show that these genetic variations may be associated with behavioral disorders, suicidal tendencies, and antisocial personality symptoms.

Various studies have been conducted to determine the genetic diversity of approximately 20 SNPs identified in the monoamine oxidase-A (MAO-A) gene and to understand the function of this gene. Among these SNPs, especially the rs6323 and rs1137070 SNP points stand out as two synonymous polymorphisms. The guanine (G) allele at rs6323 was determined to have higher enzyme activity than the thymine (T) variant. Similarly, the thymine (T) variant at rs1137070 has been associated with higher enzyme activity in individuals carrying the cytosine (C) allele. These polymorphisms show changes in the activity of the MAO-A gene, explaining the effects of genetic diversity on enzymatic functions. It has been observed that individuals with the "C" allele in the rs909525 MAOA gene are more prone to the 3R warrior version. It has been demonstrated that men with the "T" allele have higher suicide rates compared to controls [12]. Additionally, people carrying the rs6323 (MAO-A R297R Gene)- G or GG allele had higher levels of the enzyme, and in women, the G allele was associated with more outward anger, while in men it was associated with aggression. The A allele of this SNP point is associated with more MAO-A and the G allele with lower enzyme levels. In a study investigating the MAO-A gene and the antisocial consequences of violence, 2 of 5 SNPs (rs5906893, rs5906957, rs2283725, rs2072744, and rs979605) (rs5906893 and rs5906957) were associated with conduct disorder, antisocial personality, and partner violence [22].

Suggestions for the future

The MAO gene has recently become an important area to study due to its potential effects on aggression and behavioral tendencies in general. Research on the subject reveals that genetic factors can affect people's behavioral tendencies and that the MAO-A gene, the most studied of these factors, can be associated with aggressive behavior. Studies show that some polymorphisms in the MAO-A gene (such as MAO-A-L) may be associated with aggressive behavior. It has been determined that it can affect individuals' aggressive tendencies, especially when combined with environmental factors. More interdisciplinary research is needed to better understand the complex relationship between the MAO-A gene and aggression. It is important to consider in more detail the ethical and legal issues surrounding the use of genetic data in courts. This can make a significant contribution to reducing crime and making the criminal justice system more effective and fair.

To understand the role of MAO-A on aggression, epigenetic factors, and physiological mechanisms should be focused on.

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Whether aggressive phenotypes in neurodevelopmental disorders are due to changes in MAO-A requires more detailed, lengthy, and multifaceted studies. Additionally, it should be investigated how treatments targeting MAO-A can be used to prevent aggression and conduct disorder, especially for sensitive age groups such as adolescents [23,24]. Studies on the predisposition to the violence of individuals with the MAO-A gene, whether known serial killers have the MAO-A-L genotype and their long-term interaction with various environmental factors starting from childhood should be investigated [25,26].

Conclusion

The inclusion of genetic information in judicial proceedings must be carefully managed to maintain a fair legal system and protect the rights of individuals. In conclusion, the relationship between the MAO-A gene and aggression presents an interesting area of research, and further research must be conducted on a basis based on ethical standards in both genetic and legal contexts. It is thought that future research could further advance existing work on improving well-being in society and understanding psychological disorders.

Conflict of Interests
The authors declare that there is no conflict of interest in the study.

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