

# GENES INVOLVED IN BOTH DOPAMINERGIC AND SEROTONERGIC PATHWAYS AND FINANCIAL DECISION MAKING



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## **A b s t r a c t**

One of the most important assumption of rational choice theory is that individuals are purely self-interested utility maximizers. However research in economics and other social sciences has found that people can also be irrational and their choices can also be taken with some heuristics and biases. Laboratory experiments have documented substantial heterogeneity in irrational preferences, but little is known about the origins of such irrational financial behavior. Especially in recent studies, it is seen that the inheritance estimates of these differences are investigated by using quantitative and molecular genetic methods.

The main purpose of this study is to investigate the effects of dopamine and serotonin-related genes on financial decisions. For this purpose, genes associated with dopamine and serotonin were identified. Some of the studies investigating the effects of these genes on financial decision making process have been examined.

## **Introduction**

The biological basis of financial decisions and heuristics or biases, such as reward dependence, loss aversion, is not yet fully understood. However, the anatomy of choice and financial decisions has been well-studied.

In particular, studies on decision making are handled together with psychology, neurology and genetic sciences. The experimental background of these studies consists of personality tests in psychology, brain imaging techniques in neurology and genes, hormones and neurotransmitters in genetics.

The current studies from neurofinance, neuroeconomics, psychology and of course neuroscience discussed about three decision-making systems in the human brain, and dopamine and serotonin is the principal neurotransmitter that is involved in these three systems (Wargo, Baglini and Nelson, 2010):

1. An unconscious, intuitive and emotional system,

2. A conscious, rational system or executive function,
3. A system of habitual behavior that is either preprogrammed genetically or developed into habits over time.

Limbic system - the emotional center of the brain – is about some behaviors and some biases in financial decisions such as reward/approach, loss/avoidance, investment behavior or novelty seeking (Knutson & Cooper, 2005; Taylor, 2006). Any problems in this system can make you more willing to take risks, greed or dependence.

The effects of genes are not expressed directly at the level of behavior, but are mediated by their effects on brain regions responsible for specific cognitive and emotional processes (Bigos and Weinberger, 2010). On the other hand, hormones and neurotransmitters can have an effect on behaviors by changing an individual's phenotype (Soares et al., 2010), moreover these behaviors can also be influenced by genetic and epigenetic

differences (Liu et al., 1997; Meaney, 2001). Empirical findings from geneconomics and neuroeconomics (Benjamin et al., 2007; Beauchamp et al., 2011; Navarro, 2009) suggest that this holds true for economic behavior as well. Some researchers have identified a significant degree of genetic influence on variables such as change in decisions to invest in equity securities (Barnea et al. 2010), income (Taubman 1976), risk preferences (Zhong, Chew et al., 2009), cooperativeness in trust games (Cesarini et al., 2008), bargaining behavior (Wallace et al., 2007), and preferences for giving and taking risks (Cesarini et al., 2009).

Studies in healthy people and diagnosed people with mood disorders or psychiatric disorders have shown that: risk-taking or risk-avoiding behavior is associated with genetic variations in dopaminergic and serotonergic pathways. In addition, the relationship between cognitive and emotional biases and genetic variations in financial decisions has been discussed and proved in other studies. Genes such as COMT, SLC6A4, BDNF and Dopamine Receptor Genes are frequently used in such studies. Investigation of the fundamentals of financial decisions using molecular genetic methods has been studied not only with dopamine receptor genes but also with many different genes and polymorphisms. One of the genes discussed in such studies is the MAOA gene.

### 1. Dopamine, Serotonin and Some Genes

Dopamine and serotonin are necessary for normal nervous system function, and changes in the levels of these neurotransmitters contribute to some psychological disorders. Both dopamine and serotonin interact with other neuromodulators to influence choice (Doya, 2008).

Dopamine and serotonin, which are chemical messengers that transmit signals between nerve cells (neurotransmitters), are frequently used in such studies, and U.S. National Library of Medicine has identified 27 gene that associated with dopamine (CHRNA4, COMT, DBH, **DDC**, DPYS, DRD2, DRD3, DRD4, DRD5, EPB41L1, GBA, **GCH1**, GNAL, **HTR1B**, **MAOA**, OPRM1, PARK7, PRKN, RGS9, **SLC18A2**, SLC6A3, SNCA, **SPR**, **TAAR1**, TH, TOR1A, UPB1) and 14 gene that associated with serotonin (CC2D1A, **DDC**, FEV, **GCH1**, HTR1A, **HTR1B**, HTR2A, **MAOA**, **SLC18A2**, SLC6A4, SNORD115-1, **SPR**, **TAAR1**, TPH2). Given that these genes are involved in both the dopaminergic serotonergic pathways, two pathways that play critical roles in emotional processing, this gene may contribute to a series of processes involved in affective processing (Gao, Liu et al. 2017). The genes that appear to be associated with both serotonin and dopamine are: DDC gene, GCH1 gene, HTR1B gene, MAOA gene, SLC18A2 gene, SPR gene and TARR1 gene.

As seen as, the MAOA gene is one of the genes associated with both dopamine and serotonin.

Johnston (1968) defined two subtypes of MAO based on the observation that one form (A) but not the other (B) was sensitive to the irreversible inhibitor, clorgyline. The U.S. National Library of Medicine describes the MAOA gene and its role in the breakdown of neurotransmitters such as serotonin and dopamine: "The MAOA gene provides instructions for making an enzyme called monoamine oxidase A. Specifically, monoamine oxidase A is involved in the breakdown of the neurotransmitters serotonin, epinephrine, norepinephrine, and dopamine. Signals transmitted by serotonin regulate mood, emotion, sleep, and appetite. Epinephrine and norepinephrine control the body's response to stress. Dopamine transmits signals within the brain to produce smooth physical movements."

Monoamine oxidase A (MAOA) gene located in Xp11.3 spanning 15 exons containing 527 amino acids and codes for MAOA protein. The function of MAOA enzyme is to degrade monoaminergic neurotransmitters (adrenaline, noradrenaline, serotonin and dopamine) in the brain. These neurotransmitters play an important role in arousal, emotions, mood and even affecting impulse control (Ramakrishnan and Akram Husain, 2017). There are also studies linking the MAOA gene with some psychological disorders like schizophrenia, bipolar disorder and major depressive disorder. Different variants of it regulate transcription, metabolism, and signal transfer between neurons, all of which have an effect on social interactions (Craig, 2007; Spitzer et al., 2007). The less transcriptionally efficient alleles are called MAOA-L, and the more efficient are called MAOA-H (Sabol et al., 1998). MAOA-L has been found to be associated with various kinds of antisocial behavior, including violence and aggression, both in the field (Caspi et al., 2002) and in the lab (Gallardo-Pujol et al., forthcoming). McDermott et al. (2009) show an association between MAOA-L in males and behavioral aggression following provocation.

Studies revealing the association of variations in the MAOA gene with psychological disorders such as aggression and mood disorder have led to the investigation of the relationship between excessive risk-taking behavior and excessive self-esteem bias with the MAOA gene in financial decisions. Previous literature suggests may be individual variability in genetic alleles (Raine, 2008), and this variability can cause some irrational financial decisions, such that individuals with a low activity form of the gene that encodes monoamine oxidase A (MAOA-L) will be

more likely to react with aggression to challenge, and these aggressive behaviors can cause people to behave in extreme risk. The MAOA gene, which is thought to have a close relationship with aggression behavior in studies about neurobiological basis of taking economic risk, is generally considered together with gambling addiction in studies where risk taking behavior is examined in financial decisions.

Ibanez et al. (2000) studied 68 pathological gambling addicts and 68 control groups and investigated whether there is a relationship between MAOA and MAOB genes and pathological gambling disease. According to results, there were no significant differences between pathological gamblers and healthy volunteers in overall allele distribution at the MAOA gene polymorphism, but there was a significant association between allele distribution and the subgroup of severe male gamblers compared to the males in the group of healthy volunteers.

Pérez de Castro et al. (2002) studied the relationship between pathological gambling dependence and MAOA (MAOA-uVNTR polymorphism) in the serotonergic system. At the end of the study, the relationship between pathological gambling addiction and serotonergic system was emphasized. In the experiment, the allelic frequency of the 3-copy allele in MAOA-uVNTR polymorphism was found to be higher in the experimental group which was gambling dependent and lower in the control group. Zhong, Israel et al. (2009) examined the effect of the MAOA gene on gambling and insurance behaviors. The fact that people exhibit high risk taking behaviors while playing games of chance, but insuring other areas of their lives cannot be explained rationally. They found that subjects with the high activity (4-repeat) allele are characterized by a preference for the longshot lottery and also less insurance purchasing than subjects with the low activity (3-repeat) allele.

Frydman, Camerer et al. (2011) combine neuroeconomics and behavioral genetic methods to investigate the effect of monoamine oxidase-A (MAOA) on risk attitudes. As a result of the study, in accordance with the previous literature, they concluded that the carriers of MAOA-L polymorphism are more likely to take financial risks and can make better financial decisions at risk.

When looking at the triad of financial decision making, personality and genetics, it should be noted that they are all closely related. In addition, recent studies have added another

variable to this trio: Neurology. There are many studies linking MAOA uVNTR with brain functions that is realized during cognitive, emotional arousal and personality tests (Fan, Fossella vd, 2003; Meyer-Linderberg, Buckholtz vd., 2006; Buckholtz, Callicott vd. 2008; Cloninger, 1986). Additionally, some brain imaging studies have shown an activation of similar brain areas in aggression and cooperation (Nelson & Trainor, 2007; Decety et al., 2004). Moreover, brain functions during cognition, emotional arousal, personality test-takings, and working memory activation as well as the function and anatomy of specific brain regions in the limbic system were affected by the MAOA VNTR (Mertins, Schote and Meyer, 2013).

Another common gene identified for dopamine and serotonin is the DDC gene. The DDC gene provides instructions for making the aromatic l-amino acid decarboxylase (AADC) enzyme, which is important in the brain and nervous system, and this enzyme takes part in the pathway that produces dopamine and serotonin. Based on the results of studies showing that the DDC gene is associated with some psychological disorders, such as anxiety (Costas et al., 2010) and bipolar disorder (Børglum et al., 2003), it can be said that genetic variations in the DDC gene can be a candidate gene for decision making genetic studies.

Gao, Liu et al. (2017) demonstrated that the genetic variations of the DDC gene, gene contributed to individual differences in the susceptibility to framing. The framing effect in behavioral finance refers the tendency to be risk-averse when options are presented positively but be risk-seeking when the same options are presented negatively during decision-making.

The GCH1 gene provides instructions for making an enzyme called GTP cyclohydrolase 1. This enzyme is involved in the production of a molecule called tetrahydrobiopterin (BH4). Tetrahydrobiopterin is involved in reactions that produce chemicals called dopamine and serotonin neurotransmitters, which transmit signals between nerve cells in the brain.

The GCH1 gene is generally known as a gene with pain sensitivity and potential to develop chronic pain (George, Wu et al.). However, mutations in the GCH1 gene have been identified in the following 3 clinically different neurometabolic disorders: dystonia, hyperphenylalaninemia and compound heterozygote mutations of the GCH1 gene with a neurologic disorder intermediate in severity between the above disorders (Hahn, Trant and Brownstein, 2001). However, in the literature, there is no

study showing the direct relationship of this gene to decision making or financial decision making.

The HTR1B encoded by this intronless gene is a G-protein coupled receptor for serotonin (5-hydroxytryptamine).

Benko et al. (2010) examined the association between the C (-1019) G functional polymorphism, regulating the HTR1A gene expression, and impulsiveness. The C (-1019) G genotype groups, showed significant differences: GG type subjects showed significantly higher motor and cognitive impulsiveness. According to these findings suggest that the receptor gene, HTR1A, expression was involved in a continuum phenotype of impulsiveness. However, in the literature, there is no study examining the relationship between HTR1B and decision-making or financial decisions.

According to the U.S. National Library of Medicine, SLC18A2 gene encodes a transmembrane protein that functions as an ATP-dependent transporter of monoamines, such as dopamine, norepinephrine, serotonin, and histamine. Polymorphisms in this gene may be associated with schizophrenia, bipolar disorder, Parkinsonism, and other neurological/psychiatric ailments. However, there is no evidence that the SLC18A2 gene directly affects financial behaviors or financial decisions.

According to the U.S. National Library of Medicine, the SPR gene provides instructions for making the sepiapterin reductase enzyme. The sepiapterin reductase enzyme converts a molecule called 6-pyruvoyl-tetrahydropterin to tetrahydrobiopterin. Tetrahydrobiopterin helps process several building blocks of proteins (amino acids), and is involved in the production of chemicals called neurotransmitters, which transmit signals between nerve cells in the brain. Specifically, tetrahydrobiopterin is involved in the production of two neurotransmitters called dopamine and serotonin. Although it was associated with dopamine and serotonin, no direct correlation was found between the SPR gene and decision-making or financial behavior. Like the SPR gene, the TARR1 gene has been identified by the U.S. National Library of Medical. According to this, the protein encoded by this gene is a G-protein coupled receptor activated by trace amines. The encoded protein responds little or not at all to dopamine, serotonin, epinephrine, or histamine, but responds well to beta-phenylethylamine, p-tyramine, octopamine, and tryptamine. While primarily functioning in neurologic systems, there is evidence that this gene is involved in blood cell and

immunologic functions as well. There is no evidence that the TARR1 gene affects behaviors or financial decisions.

## Discussion

When the genes associated with dopamine and serotonin are examined, it is seen that some of the genes have proven to be related to decision making. In particular, the findings suggest that the MAOA gene plays a role in financial behavior and financial decision making. Studies examining the effect of the MAOA gene on risk-taking behavior in financial decisions are often addressed in conjunction with gambling addiction.

In addition to genes commonly used in the field of geneoconomics, such as COMT, BDNF, SLC6A4, studies on the effect of variations in the MAOA gene on the financial decision process are important for geneoconomics and neuroeconomics.

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