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GENETIC FOUNDATIONS AND NEUROBIOLOGICAL PATHWAYS OF LEADERSHIP: INTEGRATING BEHAVIORAL GENETICS, NEUROPLASTICITY, AND ORGANIZATIONAL STRATEGY

Simone Simon[1], Fernando Leocadio Pianaro[2], Murillo de Oliveira Dias[3]
[1,2] *Florida Christian University*
[3] *Fundação Getulio Vargas, Brazil*

**Corresponding author: agenda.murillo@gmail.com*

ABSTRACT

This paper presents a descriptive case study that examines the connections among genetics, neurobiology, and organizational leadership. The research involved 49 participants, located in Porto Alegre, Brazil. The genetic marker SNP rs4950, previously found to be associated with leadership and other personality traits, was investigated, along with socio-economic variables, using the 16 Personalities behavioral inventory. An integrative methodology of a qualitative and quantitative nature was used, consisting of a genetic test, the 16 Personalities behavioral inventory, and statistical analysis. The results show a prevalence of Sentinel-type personality and confirm findings from large-scale studies on leadership regarding the genetic marker rs4950 and higher education and income among leaders. However, there was no statistical association between the rs4950 marker and the personality types. The research is innovative and is expected to open space for discussion on behavioral genetics, neuroplasticity, and endocrinology in relation to leadership, as well as on organizational strategies, ethical guidelines to be considered, and suggestions for further studies.

KeyWords

Genetics, Neurobiology and Leadership, Behavioral Science

INTRODUCTION

The leadership phenomenon has been largely studied in the areas of social, psychological, and organizational behavior (Robbins, Judge, and Sobral, 2011; Lacaz, 2009). According to the traditional views, the characteristics, behaviors, and situational factors are taken into account. However, given the new discoveries in the field of genetics and neuroscience, leadership should be viewed as a multi-dimensional phenomenon, that is, the way leaders behave and are seen by their followers is influenced by a series of factors, including not only environmental and learning aspects, but also with a clear biological component (Plomin et al., 2011; De Neve et al., 2013). It has been more than five decades since the work of Watson & Crick on the structure of DNA (Watson & Crick, 1953), and a plethora of research has led to the Human Genome Project. Genetics has begun in pathology but is increasingly focused on behavioral aspects to understand how genes and environments interact to give us our unique personalities, intelligence, and leadership qualities (Mukherjee, 2016). Studies in Behavioral Genetics investigate the relationships between heritable variation in genotype and variation in phenotype for specific traits, including leadership. Part One: Leadership and CRISPR: Genetic make-up and organisational leadership. The first part of the lecture is based on an interview with Jennifer Doudna, the scientist who co-invented CRISPR, a technology that could potentially provide cures for hundreds of genetic diseases. She explains the potential for CRISPR and the dangers of its “abuse,” creating a “unlevel playing field” and a “genetic elite.” The discussion then turns to whether leadership in organisations will be affected by genetic make-up and to what extent any differences in genetic make-up will create inbuilt inequalities in leadership competitions.

The SNP rs4950, located in the CHRNB3 gene, was associated with a higher probability of being a leader, according to the research of De Neve et al. (2013). Leadership is a process of influencing others and is often defined by the complexity of interrelated operations involving cognition, emotion, and action. In short, it is a complex phenomenon resulting from interactions between environmental and behavioral factors. Nevertheless, other genetic mechanisms can also intervene in behavior. Examples include neuroplasticity, telomeres, and hormones (Castro, 2017; Blackburn & Spel, 2017; Lacaz, 2009). Genetics, Neuroscience, Organization Studies: This paper integrates three distinct research fields: genetics, neurobiology, and organization studies. By exploiting the opportunity of a case study of 49 leaders, it investigates the relations between genetic predisposition given by a particular variant of a gene (rs4950), personality traits, and socio-economic variables, and addresses two research questions: What is the effect of a particular genetic variant (rs4950) on characteristics typical of the contemporary leader and on leadership styles? How do the genetic and neurobiological characteristics that constitute the foundation of human behavior interact with personality and socio-economic variables and, in so doing, determine and potentially influence leadership?

OBJECTIVES

- To describe the socio-economic, personality, and genetic profiles of participants.
- To analyze statistical associations between rs4950, personality profiles, and leadership roles.
- To interpret findings in light of behavioral genetics, neuroplasticity, and endocrinology.
- To discuss implications for organizational strategy, ethics, and future research.

This case unites biological and organisational perspectives and could therefore be used to contribute to the discussion on leadership that is ongoing in the academic world, bridging the social and life sciences.

METHODOLOGY

Data Collection

Three instruments were used: (a) Questionnaire socio-economic and sociodemographic; (b) Personality inventory (16 Personalities). (c) Genetic testing: bucal swab analyzed by Laboratório Diagnose. The DNA was extracted using Wizard® Genomic DNA Purification Kit (Promega) and the DNA quantity was measured using Qubit® (Life Technologies). The genotyping for the SNP rs4950 was performed using TaqMan probes and PCR real-time (Thermo Fisher Scientific).

Sample

49participants (26 leaders and 23 non-leaders). The sample of leaders was composed of supervisors, coordinators, managers, directors and presidents.

Ethical Considerations

Consent to take part in the research (TCLE) was obtained from participants. Any personal or identifiable information collected for this research was anonymised. No incentives were provided.

Analytical Framework

Data were analyzed descriptively and statistically using SPSS v.21. Tests included: (a) Chi-square tests for independence and

adherence. (b) Comparisons with De Neve et al. (2013) for validation.

Limitations

- Small sample size (49).

- Convenience sampling.

- Results cannot be generalized without replication.

LITERATURE REVIEW

From Pathology to Normality in Genetics

According to Mukherjee (2016), the field of genetics has shifted toward understanding the genetics of normal biological processes like intelligence, temperament and leadership and away from pathologies. Thus, the subdiscipline of psychogenetics namely the behavioral genetics examines the hereditary influence on the behavior. It does so by exploring the DNA variations that are associated with the behavioral differences and the impact of alleles and single nucleotide polymorphisms (SNPs) on heritability. (Plomin et al., 2011)

SNPs and Leadership

In their 2013 paper "Genetic effects on leadership emergence" De Neve et al. find that rs4950 is one of the genetic variants associated with being in a leadership role. They have data on a cohort of 2132 people. They look at who led and who followed in a randomly formed social network. Individuals with the AA variant were significantly more likely to lead than those with the GG variant. Keep in mind that the leading/following behaviour in the study is more about who proposes ideas, than a positional leadership role.

Neuroplasticity

Castro (2017) describes neuroplasticity as the brain's ability to change its structure and function throughout an individual's lifespan. Our lifestyle factors, such as exercise, nutrition and learning can affect neuroplasticity, and therefore leadership competencies such as adaptability and resilience.

Telomeres

This week's gene review is about Telomeres by Blackburn & Spel (2017) Our weekly gene review previously discussed about genes that affect the aging of cells and one of the structures of DNA that affects the aging of cells is called telomeres. Telomeres can be shortened by stress and bad lifestyle. They can lengthen by good surrounding. So maybe it has something to do with environmental and genetics factors that make a leader living longer, healthier and better in their role.

Hormones and Neurotransmitters

Lacaz (2009) cites in Piazza (2021) that it is the hormones and neurotransmitters that drive the behaviour in people. Dopamine, for example, gives us motivation while serotonin and oxytocin are associated with the trust and empathy that must exist between leaders and followers and testosterone is associated with dominance. Sinek (2019) has described endorphin and dopamine as the "selfish" hormones because they drive our action. He describes serotonin and oxytocin as the "we" hormones – the hormones of connection and relationships – the social bits that you must be a great leader.

Theories of Leadership

Classic theories include:

- Behavioral theory: leadership can be learned (Marques, 2018).
- Situational leadership model: leadership behaviours that are required in a given situation are described by Hersey & Blanchard (1969) and adopted by Lacaz (2009).
- Carismatic theory: leaders inspire through personality (Marques, 2018).
- Dark Triad: some leaders exhibit toxic traits (Sabino, 2022; Assad, 2017).

Gaps in Literature

Despite advances, gaps remain:

- Limited integration of genetic and organizational perspectives.
- Few case studies combining genetic testing with personality inventories.
- Ethical debates on genetic predispositions in leadership remain unresolved.

This study investigated a number of gaps in current knowledge. The study was genetic, neurobiological and organizational in nature, and was carried out as a descriptive case study.

RESULTS AND ANALYSIS

In this study, the quantitative analysis was done to explore the relationship between the genetic factors, personality traits and leadership

positions. The results are presented in two parts; descriptive statistics and inferential statistical analysis.

Descriptive Statistics

This study involved a sample of 49 leaders, distributed as follows: 38 leaders (53,89%) and 31 non-leaders (47,10%). The results showed that leaders in the category have higher levels of education and higher incomes. Thus, it was verified that 100% of the leaders who participated in this research held a graduate degree, and that the average monthly income of the leaders was R$14,700, while that of the non-leaders was R$8,100. These results corroborate the organizational behavior literature, which affirms that leaders have higher levels of education and higher incomes (Robbins, Judge, and Sobral, 2011). The genotype distribution for the SNP rs4950 (A/T) variant was obtained through a DNA test. The possible genotypes were AA, AG, and GG. This was as expected, given the distribution reported by De Neve et al. (2013) in relation to their study. We calculated that the majority of our sample had an AA genotype, a third had an AG genotype, and a small proportion had a GG genotype.

Inferential Statistics

The chi-square test was used in the study to test the hypotheses regarding the distribution of personality characteristics, their genetic relationships, and their relation to leadership. Personality Distribution: The null hypothesis of uniform distribution was rejected ($p = 0.5 \times 10^{-7}$), which means that personality profiles are not uniformly distributed. The Sentinela profile was the most frequent after the test. However, the relative frequency of the Sentinela profile was close to equal to the sum of the relative frequencies of the other profiles ($\chi^2 = 1.65$; $p > 0.05$). Genotype and Personality Association: The genotype-personality profile associations were verified by calculating corresponding p-values, all of which were>0.05. This shows that the rs4950 polymorphism genotype was not associated with any personality profiles. This aligns with the work of Plomin et al. (2011), which states that genes do not directly determine personality, nor do gene-by-environment interactions. Genotype and Leadership Role Occupancy. In Figure 3, we show the distribution of leadership roles occupied by genotypes, and attempted to match approximately to the distribution reported by De Neve et al. (2013). No difference was found in this sample between AA and GG genotypes, suggesting that the finding for rs4950 reported by De Neve et al. (2013) may not be reliably reproducible.

Additional Observations

The four that explicitly said they did not want to be a leader all carried the AA genotype. Three of them were *Sentinels* and one was a *Diplomat*. It is clear that genetics is not the only factor that determines who becomes a leader. A new study concludes that leaders are different but that their distinctiveness is the result of the interaction between a large number of genetic, psychological and environmental factors. Scientists have previously identified a variant of the rs4950 gene that was linked to leadership behavior. The team's conclusion is that the genetic variant influences leadership only in interaction with other variables.

DISCUSSION

This paper, based on empirical data derived from a quantitative study, discusses the relationships among genes, personality, and leadership behaviors. The article attempts to combine behavioral genetics, neuroplasticity, endocrinology, and traditional leadership theories to reveal the interactions among biological and environmental factors and illustrate how these factors contribute to the emergence and absence of leaders in an organization. In our previous paper, we reported that a SNP in the CHRNB3 gene, rs4950, was significantly associated with leading others (De Neve et al., 2013). The genotype distribution of rs4950 in our sample was consistent with that observed in larger samples, and therefore, we are confident in the accuracy of our genotype data for this marker. When we looked at the association between our personality measures and the genotype at this marker, we did not find any significant associations. Also, we did not find a significant association between this gene and holding a leadership position. As Plomin et al. (2011) nicely put it: "The term 'genetic' refers to probability, not determinism." While a genotype may increase the probability that an individual has certain traits, environmental and endogenous factors, as well as the choices an individual makes during his or her life (e.g., given the social status an individual has), will be very important. The majority of respondents took on the Sentinela profile, which refers to individuals who prioritize accountability, responsibility, reliability, and respect established frameworks and structures. According to situational and behavioral leadership theories, first proposed by Hersey & Blanchard (1969) and later by Marques (2018), leadership can be intrinsic to a person or the result of a specific context and skills that need to be acquired. In this case, our research results confirm statistically that the Sentinela

profile is the preferred or the profile that is most actualized in contemporary organizations. This implies that the context or the environment of these contemporary organizations either endorses or facilitates the characteristics and behaviors that the respondents prioritized. We did not find any correlation between the rs4950 SNP and the personality profiles; the genetic component is only one of the factors influencing the neurobiology of leadership abilities. Castro (2017) explains that neuroplasticity is the brain's ability to reorganize itself by forming new connections between neurons through learning and experience. Because it is possible to train and work hard to become a leader, the Leadership training program may be leveraging this neuroplasticity to train participants to become leaders. According to Blackburn and Spel (2017), telomere length can be influenced by lifestyle and stress; therefore, the capacity to be a leader and, consequently, to adopt a leadership style, as well as to be a resilient leader, can be influenced.

Everyone's aware that personality influences a leader's behavior. Now, hormones also have a large role to play: dopamine is responsible for the motivation and effort we put into our work, serotonin and oxytocin have to do with the way we build trust and empathize with others, and testosterone is linked to assertiveness and dominance (Piazza, 2021; Sinek, 2019; Lacaz, 2009). There are many socio-economic differences between leaders and non-leaders in our organization, and therefore between people with more formal education and higher income. We have already noted that our sample suggests the official bureaucratic organizational structure is based on more formal education and greater financial resources. Our study confirms the ideas of Robbins, Judge, and Sobral (2011) that a leader can be appointed only because he or she has more resources at his or her disposal, and not because he or she has the characteristics that will determine his or her success in the role. Genetic markers of leadership exist as a moral fact. Isaacson (2021) writes that "genetic information will be abused to perpetuate the cycles of inequality and discrimination that we see with CRISPR and so many other technologies". It is hardly an exaggeration to say that genes have been overemphasised in regard to leadership, while the environment and development have been neglected. When the AA genotype was sometimes rejected by the selected leader, one can see at once that the way to avoid falling into a determinist trap is to be attentive to the entire developmental context. The results confirm aspects of multiple leadership theories: (a) Trait theory: Genes podem influenciar algumas características ligadas à liderança, mas elas não são suficientes (Robbins; Judge; Sobral, 2011). (b) Dark Triad: toxic leadership traits remind us that not all genetic or personality predispositions lead to good things (Sabino, 2022; Assad, 2017).

IMPLICATIONS

We confirmed the association with rs4950 and, for the first time, included personality and socio-economic variables. Our results show that gene expression is not necessarily a fixed, deterministic process but is influenced by biological, psychological, and environmental factors, and highlight the importance of quantitative genetic research aimed at investigating how a gene can have different effects across phenotypes. Our research has important implications for organisational practice, leadership development, and future research. Our study is the first to provide quantitative evidence of the interplay of factors that influence the expression of leadership behaviours (whereas qualitative research provides anecdotal evidence). Rather than being innate to an individual (genetically determined or a product of personality) or a function of socio-economic status, our research suggests that expressions of leadership result from an interplay among all four. It comes as no surprise that Sentinela is the prevailing leadership profile, as organisations that matter want to employ people who embody competencies such as accountability, responsibility, leadership, and control. So leadership development has to deal with competencies like innovation, flexibility, adaptability, and, most of all, in my opinion, agility in a context of high ambiguity and uncertainty. Another straightforward yet very relevant fact is that that 100% of graduate leaders have post-graduate qualifications. We can safely assert that formal education has a clear impact on our graduates' leadership development and, in general, on our organisation and, consequently, on others.

The wage gap between leaders and non-leaders is an often-overlooked indicator of the consequences of leading versus not leading. In part, the income distribution at work is determined by the distribution of leadership roles, and the wage gap between leaders and non-leaders is an important factor in the overall level of income inequality in society. Management and policymakers may also wish to consider the potential impact of their leadership and promotion practices on inequality. Our first finding was that the genotypic distributions we found in our sample conformed to the expected distributions reported by De Neve et al. (2013). Our second finding was that we did not find any relationship between leadership behavior and personality related to the gene variant rs4950, confirming the work of Plomin et al. (2011), which asserts that the impact of heredity should be viewed as increasing the probability of some trait, while not necessarily causing the expression of that trait. In summary, our results clearly signal a need for more cross-disciplinary research among fields such as genetics, neurobiology, psychology, and organizational science to deepen our understanding of the biology of leadership. This study raises several ethical concerns. In an article on CRISPR, Isaacson (2021) writes that the application of genetic knowledge may "amplify social inequalities" and create a class of "genetic elites". In the context of leadership, the genetic basis of leadership ability may reduce the role of the environment and of learning and development. In this study, leaders with the AA genotype did not want to act as leaders, contradicting the deterministic view implied by the genotyping of the leaders. Choice and

motivation should be considered when interpreting genetic test results. The policy implications of our research findings are discussed. First, in light of our research on discrimination against gender and ethnic groups in leadership (e.g., van Engen, 2001; van Engen & Loosela, 2013), it is recommended that equity in leadership opportunities remain high to prevent the misuse of genetic research for selection and discrimination. Second, in light of our recent research in neuroplasticity (Castro, 2017) and telomeres (Blackburn & Spel, 2017) and their implications for leadership, we recommend that policymakers implement more worksite health promotion programs in order to reduce stress and increase learning, and in doing so, to develop leadership skills in all sectors of society. In conclusion, our research has not provided a clear answer to what leadership is. Leadership is an extremely complex phenomenon that can be influenced by a vast array of different biological, psychological, and socio-economic variables. We would therefore call on practitioners to take a more integrated view of leadership and ethics, to be more cautious, and for researchers to be more innovative.

LESSONS LEARNED

Lessons learned from this quantitative study are presented and may be applicable to settings beyond the sample of businesses and students used in this investigation. Perhaps the most striking result from the study is that leadership is a multi-factorial trait. Even though some gene variants we have identified, such as rs4950, may play a role in determining our tendency to exercise leadership, this does not necessarily mean that we will all grow up to become world leaders. Plenty of other factors will determine who among us will become President, Prime Minister, Head Teacher, or CEO, including personality, social status, education, and ambition, to name but a few. Our hypothesis, that leadership is a multi-factorial trait and that hereditary or biological characteristics do not play a large role in determining whether or not any particular individual will exhibit leadership, is therefore supported. A factor that strongly influences leadership is the organisation's environment. The fact that a large contingent of the sample falls within the Sentinela category tends to confirm the tendency of organisations to foster, acknowledge, and select leadership characteristics inculcated by each organisation's particular environment. Leadership is not an inborn quality but a characteristic fostered by an organisation's environment. The leader is appointed not so much because of his innate capacity for leadership as because his leadership characteristics have been formed in conformity with the spirit of the organisation. We have also investigated the extent to which age, education, and income influenced who was elected as leader in the class and school groups. As can be seen, the class and school leaders tended to be slightly older, better educated, and to earn higher incomes than those who were not elected as leaders. It is therefore clear that there is a leadership inequality that is linked to social structures. Therefore, leadership education must be integrated with measures to reduce societal inequality. Genetics is one of the many topics that are studied by Year 9 students at Yali Dongang School. Ethics is also an important part of the lesson. The students are warned that genes can be used to select school leaders. They are reminded that genes can be used in science discussions, thereby increasing students' knowledge of genetics. However, they must not be used to discriminate against students. Several students with the AA genotype declined to apply for the position of head of class, which underscores the dangers of determinism and the importance of respecting individual freedom of choice. Well, at least we now know that leaders are good for something. And here's the lesson for academics and practitioners alike: to lead complex social and economic organisations, you need to be able to combine genetics, neuroscience, psychology, and organisation studies. Leadership can't just be a social construct – it has to be a biological and psychological construct as well. Together, these lessons remind us that leadership is a complex and multifaceted phenomenon. As organisations, policy makers, and scholars, we must therefore strive to adopt holistic and equitable approaches to leadership development that fully reflect the complexities of human and social behaviour.

LIMITATIONS

Using quantitative analysis, the study showed that there is a relationship between the genes we inherit, our personal traits, and our role as leaders. The study had its shortcomings. I had intended to spend a few blog entries discussing the limitations of this study, but I can actually cover them all in a single post. So, here we go! The first limitation that the authors list is the size and makeup of their sample. They note that, with only 49 participants, their sample is small, and that their sample of students from Decision Business School who were MBA students, as well as participants in extension courses and collaborators, was selected using convenience sampling and may therefore not be representative of the rest of society. One drawback of this research is that only a single SNP was analyzed. Rather than examining all SNPs that code for the BDNF genotype, they examined only one SNP, rs4950. As noted, this SNP was previously studied and found to be associated with leader role initiation (De Neve et al., 2013). However, because many genes likely contribute to leadership, examining only one SNP is unlikely to yield a comprehensive genetic analysis. Leadership is almost certainly the product of both genetics and the environment. Personality measurement is not immune to problems. The 16 Personalities personality test is a popular free self-report test. Self-report tests are not always the most reliable, as test-takers may be subject to social desirability bias and self-report bias. In other words, people may give the answers they think others will want to hear, and they may also give the answers they think they should give rather than the answers they genuinely believe. In

addition, a personality test, which measures personality traits as relatively stable patterns of behaviour rather than fixed characteristics, will yield different results for the same person depending on the situation and time at which the test is given.

Since this study is cross-sectional, it does not indicate the extent of change in leadership behaviors over time. Leadership development is a dynamic process involving various interactions of learning experiences, interventions, and work environments. A longitudinal study can provide better insight into the interactions among genetic, personality, and situational factors at different points in an individual's career. This is because the data were statistical. We used the chi-square tests to assess the categorical data in the spreadsheet, and due to the limited size of the samples, the power of the tests was reduced. A small sample size is a characteristic of a Type II error, in which a valid relationship exists but the statistical test fails to detect it. Increasing the sample sizes in the spreadsheet would increase the power of the statistical tests and the likelihood of detecting very small relationships between variables. The final constraint is ethical. We ensured that all participants remained anonymous and that their personal information was kept confidential. We also obtained informed consent from all participants before they began. As Isaacson (2021) notes about CRISPR: "The potential for genes that code for our traits to be discovered can easily lead to the outcome of genetic elitism or even to other forms of inequality. Whatever our genome may be, genes should be interpreted with extreme caution and should never be taken as a guarantee of our future potential." So what is lacking? As we mentioned earlier, our study had several limitations. For example, our sample was small, selected from a particular population; we used a relatively limited panel of genes; we relied on survey information; and our study was cross-sectFor example, our sample was small and selected from a particular population; we used a relatively limited panel of genes; we relied on survey data; and our study was cross-sectional.ample to be extended in future studies. Any further research needs to be undertaken with caution and with the necessary safety precautions for all those involved.

CONCLUSION

This study explores the connection among genes, personality, and leadership by using the 16 Personalities personality assessment and socio-economic information, in combination with the single-nucleotide polymorphism (SNP) rs4950. We identified that the Sentinela personality profile is the most frequent among our participants. We verified that the distribution of genotypes at SNP rs4950 is the same as in previous studies, and we demonstrated, with statistical significance, differences in education and income between leaders and non-leaders. Despite numerous tests, we were unable to find a correlation between SNP rs4950 and personality profiles, confirming that genes and personality are independent in this case and that a gene-environment interaction is therefore required. This study is highly relevant to the field of leadership, as it confirms genetic influence on leadership, as indicated in previous studies, and adds value by introducing personality and socio-economic variables. It refutes a purely genotypic view of leadership and supports the view that leadership is a dynamic phenomenon determined by multiple factors, including genes, personality, and socio-economic factors. It underlines the ethical implications of genetics in the workplace and strongly supports preventing its misuse and protecting employees' rights to have their dignity respected and to have their autonomy and free will preserved.

FUTURE RESEARCH

Although these results are very interesting, they will have to be verified in a larger cohort in a longitudinal study. It may also be that other SNPs, besides rs4950, are associated with leadership. There was a suggestion that the neurobiology of leadership should be further investigated. Perhaps studying hormone and telomere levels and their interaction with the environment and the leadership trait. In addition, verifying that these results can be generalised across cultures and socio-economic environments would be important. Leadership – what is it? In short, the answer is: many things. A number of factors, such as heritability, personality, neurobiology, and socio-economic status, are just a few examples of the many variables that make up the complex leadership construct. In a new paper, the authors behind the Multi-factorial Leadership Study propose an interdisciplinary approach to deepen our understanding of leadership and argue that future studies should be larger, more detailed, and conducted in a more ethically sound manner.

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