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Original Article

Impact of Attention Deficit Hyperactivity Disorder on Entrepreneurial Behavior: A Neurobiological Approach

Impacto del Trastorno por Déficit de Atención e Hiperactividad en el Comportamiento Empresarial: Un enfoque neurobiológico

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Abstract

The objective of this study is to determine the relationship between Attention Deficit Hyperactivity Disorder (ADHD) and entrepreneurial behavior, especially in characteristics such as risk-taking, creativity, and decision-making. Three groups of ten individuals (5 women; age 36.3 ± 14.0) were selected using social media platforms: one group with ADHD (four participants), one group of entrepreneurs (three participants), and one control group without ADHD or entrepreneurial experience (three participants). 10-question interviews, tailored to their respective profiles, were conducted individually via Zoom. After interviews transcriptions, significant statements were extracted for data analysis. Participants were also instructed to play the Iowa Gambling Task (IGT) from an online platform to assess decision-making and risk-taking. Individual data were compiled, compared and statistically processed with Microsoft Excel. As results, comparing interview statements between individuals with ADHD, entrepreneurs, and the control group, in terms of risk-taking, attention, and creativity showed that individuals with ADHD can bring unique traits and skills to entrepreneurship, while entrepreneurs have specific strategies for managing distractions and maintaining focus. The control group emphasizes organization and analysis rather than creativity. The findings from the IGT suggested that people with ADHD may exhibit impulsive tendencies and difficulty evaluating the long-term consequences of their actions. Entrepreneurs were willing to take calculated risks to seize opportunities and achieve their goals, and they were also aware of the need to limit risk and make prudent decisions to protect their investments. The control group highlighted the individual differences in risk-taking in randomly selected individuals, without any special condition. They showed a certain caution in opting for low-risk choices. In conclusion, the study underscores the importance of considering individual and contextual factors in decision-making processes, incorporating neurobiological aspects of ADHD. Although available data did not directly examine the influence of these factors on entrepreneurship success, it highlights the significance of understanding the complex influences involved in decision-making.

Keywords: ADHD; entrepreneurship; decision-making; risk-taking; creativity; Iowa Gambling Task; neurobiological approach; brain; genetics factors; environmental factors.

Resumen

El objetivo de este estudio es determinar la relación entre el Trastorno por Déficit de Atención con Hiperactividad (TDAH) y el comportamiento emprendedor, especialmente en características como la asunción de riesgos, la creatividad y la toma de decisiones. Se seleccionaron tres grupos de diez individuos (5 mujeres; edad 36,3 ± 14,0) utilizando plataformas de medios sociales: un grupo con TDAH (cuatro participantes), un grupo de emprendedores (tres participantes) y un grupo de control sin TDAH ni experiencia emprendedora (tres participantes). Las entrevistas de 10 preguntas, adaptadas a sus respectivos perfiles, se realizaron individualmente a través de Zoom. Tras la transcripción de las entrevistas, se extrajeron las afirmaciones significativas para el análisis de los datos. También se indicó a los participantes que jugaran a la Iowa Gambling Task (IGT) desde una plataforma en línea para evaluar la toma de decisiones y la asunción de riesgos. Los datos individuales se recopilaron, compararon y procesaron estadísticamente con Microsoft Excel. Como resultados, la comparación de las declaraciones de las entrevistas entre individuos con TDAH, emprendedores y el grupo de control, en términos de asunción de riesgos, atención y creatividad, mostró que los individuos con TDAH pueden aportar rasgos y habilidades únicos a la iniciativa empresarial, mientras que los emprendedores tienen estrategias específicas para gestionar las distracciones y mantener la concentración. El grupo de control pone más énfasis en la organización y el análisis que en la creatividad. Los resultados del IGT sugirieron que las personas con TDAH pueden mostrar tendencias impulsivas y dificultad para evaluar las consecuencias a largo plazo de sus acciones. Los empresarios estaban dispuestos a asumir riesgos calculados para aprovechar las oportunidades y alcanzar sus objetivos, y también eran conscientes de la necesidad de limitar el riesgo y tomar decisiones prudentes para proteger sus inversiones. El grupo de control puso de manifiesto las diferencias individuales en la asunción de riesgos en individuos seleccionados al azar, sin ninguna condición especial. Mostraron cierta cautela a la hora de optar por opciones de bajo riesgo. En conclusión, el estudio subraya la importancia de considerar los factores individuales y contextuales en los procesos de toma de decisiones, incorporando los aspectos neurobiológicos del TDAH. Aunque los datos disponibles no examinaron directamente la influencia de estos factores en el éxito empresarial, pone de relieve la importancia de comprender las complejas influencias que intervienen en la toma de decisiones.

Palabras clave: TDAH; iniciativa empresarial; toma de decisiones; asunción de riesgos; creatividad; Iowa Gambling Task; enfoque neurobiológico; cerebro; factores genéticos; factores ambientales.

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Introduction

Defining ADHD

Attention deficit Hyperactivity Disorder (ADHD) is a neurodevelopmental disorder characterized by symptoms of inattention, hyperactivity, and impulsivity. In recent years, there has been increasing interest in understanding the relationship between ADHD and entrepreneurship. The biological perspective of ADHD in entrepreneurship research suggests that certain traits associated with ADHD, such as high levels of creativity, risk-taking behavior, and impulsivity, may be beneficial for entrepreneurial success (Verheul et al., 2015).

Research studies have shown that individuals with ADHD tend to have higher levels of creativity, which is a valuable asset for entrepreneurs who need to generate novel ideas and solutions to complex problems (Boot et al., 2020).

Additionally, individuals with ADHD tend to be more willing to take risks, which can be advantageous in entrepreneurial contexts where uncertainty and ambiguity are common (Khalid & Sekiguchi, 2018). However, the same impulsivity that can lead to risk-taking behavior may also pose challenges for entrepreneurs, as it can lead to poor decision-making and difficulties with planning and organization (Khalid & Sekiguchi, 2018).

From a biological perspective, the underlying causes of ADHD in entrepreneurship research have been attributed to genetic factors and abnormalities in brain structure and function. Studies have shown that ADHD has a strong genetic component, with heritability estimates ranging from 78% to 88% (Faraone & Larsson, 2019).

Additionally, research has demonstrated differences in brain structure and function in individuals with ADHD, particularly in the prefrontal cortex and the dopamine system (Arnsten, 2009).

ADHD symptoms

The symptoms of ADHD can include difficulty focusing, excessive movement, and impulsive actions. This disorder can impact many aspects of a person's life, including their academic and professional achievements, social relationships, and daily functioning (Elmaghraby & Garayalde, 2022).

If left untreated, ADHD can lead to low self-esteem and poor social function in children. In adults, ADHD may lead to increased self-criticism and sensitivity to criticism due to past experiences of criticism. ADHD is more commonly diagnosed in boys than girls, but this is due to differences in how symptoms present rather than a difference in likelihood of having the disorder (Elmaghraby & Garayalde, 2022).

ADHD is frequently identified at an early age, when the child encounters problems in school or with schoolwork. It is estimated that 8.4% of children and 2.5% of adults have ADHD (Danielson et al., 2018).

Causes of ADHD

ADHD, much like other medical and psychiatric conditions such as asthma and schizophrenia, is influenced by a combination of multiple genes and non-inherited factors, as well as their interactions. The development of ADHD cannot be attributed to a single cause and being exposed to a risk factor does not always lead to the disorder (American Psychiatric Association [APA], 2013).

Moreover, our genes can have an indirect impact on our risk of developing a disease by interacting with our environment. For example, our genes can make us more or less sensitive to environmental toxins or psychosocial stressors. Additionally, the genes we inherit can also affect our exposure to certain environmental risks. For example, people who inherit a genetic predisposition to addiction may be more likely to grow up in environments where drugs are readily available (Faraone & Larson, 2019).

The genetic hypothesis

There is significant evidence that ADHD has a strong inherited component, according to a variety of study designs. Family studies have consistently shown higher rates of ADHD in parents and siblings of affected individuals, with a two- to eight-fold increased risk compared to unaffected controls.

Twin and adoption studies have shown that ADHD is a heritable disorder, but environmental factors also play a role. This means that people with a family history of ADHD are more likely to develop the disorder themselves, but environmental factors such as exposure to toxins or psychosocial adversity can also increase the risk (Sprich et al., 2000; Thapar et al., 1999).

Mean heritability estimates for ADHD are around 79%, but this suggests that noninherited factors may also contribute to the disorder (Lichtenstein et al. 2010).

Moreover, People with ADHD are more likely to have other mental health problems, such as autism, dyslexia, and depression. This is because the same genes and environment that increase the risk of ADHD can also increase (Faraone & Larsson, 2019).

The brain dysfunction hypothesis

Individuals with ADHD exhibit structural differences in their brains compared to those without the condition. According to a study by Hoogman et al. (2017) the brains of children with ADHD tend to be slightly smaller than those of children without the condition and take longer to mature.

These differences in brain volume exist in various regions that relate to motivation, memory, and emotional regulation, such as the amygdala and hippocampus. However, it's important to note that brain size does not have an impact on intelligence.

A report from the National Institutes of Health in 2007 (NIH, 2007) suggested that children with ADHD experience delays in brain maturation in specific areas. Most notably, the front of the cortex, which is responsible for cognitive control, attention, and planning, experiences the most significant delays. Conversely, the motor cortex, which is related to restlessness and fidgeting, matures faster in children with ADHD.

The frontal lobe is responsible for controlling cognitive functioning, including attention, impulse control, and social behavior. In people with ADHD, some parts of the frontal lobe may develop at a slower pace, leading to impaired cognitive abilities. The premotor cortex and prefrontal cortex, which are components of the frontal lobe responsible for motor activity and attention, may also demonstrate reduced activity in individuals with ADHD (Faraone & Larsson, 2019).

Brain structure and function in ADHD

Hoogman et al. (2017) compared the brains of 1 713 people with ADHD to those of 1 529 healthy individuals. Magnetic resonance images of the brains of the 3 242 participants, who ranged in age from 4 to 63 years, were collected. The researchers found that the volume of the whole brain and five brain regions below the cortex were smaller in children with ADHD than in those without ADHD.

The topic of brain mechanisms has been a top priority for Faraone et al. (2015) and his team since they published their paper on ADHD. Due to the extensive literature on the ADHD brain, summarizing it was challenging. However, they managed to capture its complexity using eight pictures (Faraone, 2017). Two images from Faraone's (2015) were selected, and we present it here as Figure 1.

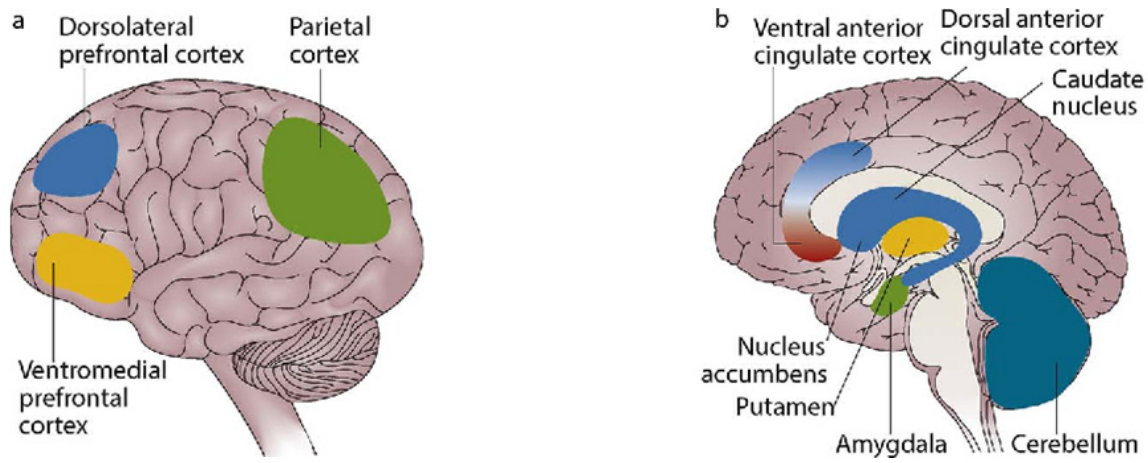

Figure 1. Brain mechanisms in ADHD

(a) The cortical regions (lateral view) of the brain play a role in ADHD. The dorsolateral prefrontal cortex is associated with working memory, the ventromedial prefrontal cortex with complex decision making and strategic planning, and the parietal cortex with attention orientation. (b) ADHD affects the subcortical structures (medial view) of the brain. The ventral anterior cingulate cortex and the dorsal anterior cingulate cortex are responsible for affective and cognitive aspects of executive control. Together with the basal ganglia (including the nucleus accumbens, caudate nucleus, and putamen), they form the frontostriatal circuit. Neuroimaging studies have revealed structural and functional abnormalities in all these structures in individuals with ADHD, extending into the amygdala and cerebellum (Faraone et al., 2015).

Brain mechanisms implicated in ADHD

- *Activation Differences:* Studies have found that individuals with ADHD show different patterns of activation in the brain compared to individuals without ADHD, particularly in regions related to attention, cognitive control, and reward processing (Faraone, 2017).
- *Dopamine Transporter Reductions:* People with ADHD have been found to have a deficiency of dopamine transporters in the brain, which can affect the regulation of dopamine levels (Bacanlı et al., 2021). Dopamine plays a role in pain processing, mood, sleep, attention, motivation, learning, heart rate and movement. The lack of dopamine therefore leads to problems of motivation, decreased intellectual performance, attention, memory, difficulty managing stress, with mood swings, fits of rage and high impulsivity. Research indicates that an elevation in dopamine levels can help alleviate the symptoms of ADHD, implying that dopamine plays a role in the disorder (Faraone, 2017).
- *Prefrontal Cortex Differences:* Fernández-Jaén et al., (2015) found that the prefrontal cortex reached its maximum thickness (a sign of maturity) at about 10.5 years of age, compared to 7.5 years of age in children without ADHD. The prefrontal cortex is involved in many cognitive functions such as decision making, reasoning, personality expression, planning and social cognition.
- *Basal Ganglia Dysfunction:* The basal ganglia are nuclei involved in motor, cognitive, and habit formation activities. Researchers found that people with ADHD had a 2.4 times higher risk of diseases related to the basal ganglia (as well as the cerebellum) than people without ADHD (Curtin et al., 2018).
- *Frontal-striatal Circuitry:* The frontal-striatal circuit, a network of brain regions involved in cognitive control and decision-making, has been found to be impaired in individuals with ADHD, potentially leading to problems with impulsivity and decision-making (Emond et al., 2009; Seidman et al., 2005).
- *Default Mode Network Differences:* The default mode network, a network of brain regions that are active when the brain is at rest, has been found to be different in individuals with ADHD compared to those without, potentially leading to problems with attention and self-reflection (Faraone, 2017).
- *Cortical Thickness Differences:* Studies have found that individuals with ADHD have differences in cortical thickness in various regions of the brain, potentially contributing to difficulties with attention and executive functions (Faraone, 2017).
- *Structural Brain Abnormalities:* Lastly, studies have found that individuals with ADHD have structural abnormalities in various regions of the brain, such as the corpus callosum and cerebellum, which can affect communication between brain regions and lead to problems with motor control and coordination (Seidman et al., 2005).

Environmental reasons

A US study examined the impact of early environmental exposures on ADHD symptomatology in children (Eubig et al., 2010). The authors found that exposure to certain environmental factors, such as lead, tobacco smoke, and Polychlorinated Biphenyls (PCBs), during pregnancy and early childhood may increase the risk of ADHD. Additionally, the study found that prenatal exposure to maternal stress, depression, and anxiety may also contribute to the development of ADHD in children.

For an infant born prematurely, the relative risk of ADHD is increased by a factor of 2.6 compared to a child born at term. This would be due to early brain development (Bange, 2011).

It is important to note that despite extensive research and understanding of ADHD, the exact cause of this condition remains elusive. While various factors, including genetic, environmental, and neurobiological factors, have been implicated in its development, a definitive cause has not yet been identified. The complex nature of ADHD highlights the need for ongoing research and exploration to deepen our understanding of this condition (Elmaghraby & Garayalde, 2022).

Additionally, the heterogeneity of ADHD presentations further complicates the identification of a singular cause, as individuals with ADHD can exhibit different symptom profiles and respond differently to interventions (Shaw et al., 2007).

Continued scientific investigations and advancements in the field will provide valuable insights into the underlying mechanisms of ADHD and help shed light on its origins. By further unraveling the complexities surrounding ADHD, we can strive towards more effective diagnostic methods, tailored interventions, and enhanced support systems for individuals affected by this condition (Shaw et al., 2007).

Overview of entrepreneurship and its characteristics

Successful entrepreneurs are those who identify and exploit opportunities. Make quick decisions under uncertainty, who are hard workers, determined to achieve their goals, willing to take risks, and "jacks-of-all-trades" who perform a wide range of professional tasks (Lazear, 2005).

The tasks associated with this conduct can be accomplished by an individual or a group and usually necessitate creativity, motivation, and a willingness to take risks (Barringer & Ireland, 2020).

Innovation and Creativity

Innovation is the specific tool of entrepreneurs, the means through which they exploit change as an opportunity for another enterprise or another service. It is able to be introduced as a discipline, able to be learned, able to be exercised. Entrepreneurs should consciously seek out the sources of innovation, change and their symptoms that point to the possibilities of successful innovation. They may use

new technologies, creative marketing strategies, or unique approaches to solving problems in order to differentiate their offerings from those of their competitors. They have to understand and implement the principles of successful innovation (Drucker, 2006).

Innovation and creation are closely related. Creativity is often considered one of the key characteristics of entrepreneurs. Creativity can be defined as the ability to combine ideas or concepts to produce something new and valuable (Yeh et al., 2022). Entrepreneurs demonstrate creativity in their ability to see opportunities where others see only challenges or obstacles. This ability to identify unique opportunities and innovate can help them succeed in competitive environments (Davis, 2010).

Risk-taking

Entrepreneurship is often associated with taking risks, as entrepreneurs need to make decisions in an uncertain environment where outcomes are not always guaranteed (Antoncic et al., 2018). Risk-taking behavior is an integral part of entrepreneurship, as it allows entrepreneurs to identify and pursue opportunities that others may overlook (Barringer & Ireland, 2020). However, risk-taking can also lead to failure, which is a common experience for many entrepreneurs (Villanueva & Martins, 2022).

Entrepreneurs face several types of risks, including financial risk, market risk, and technological risk (Barringer & Ireland, 2020).

Entrepreneurs' risk-taking behavior is influenced by a variety of factors, including personality traits, cognitive biases, and environmental factors such as cultural norms and institutional frameworks. Some entrepreneurs are naturally more inclined to take risks, while others are more risk-averse and prefer to minimize risk (Barringer & Ireland, 2020).

Despite the potential downsides of risk-taking, research suggests that it is a necessary component of successful entrepreneurship. Studies have found that entrepreneurs who are willing to take risks are more likely to achieve higher levels of growth and profitability than those who are risk-averse (Zacharakis & Shepherd, 2001).

Resilience and persistence

Resilience and perseverance are important qualities for entrepreneurs to possess as they enable them to overcome obstacles, adapt to changes, and achieve their objectives. To cultivate resilience and perseverance, entrepreneurs must remain focused on their goals, embrace their failures as learning opportunities, seek out positive relationships and support, prioritize their physical and mental wellbeing, and sustain their motivation. By developing these qualities, entrepreneurs can better manage the challenges of entrepreneurship and increase their likelihood of success (Korber & McNaughton, 2023).

Passion

Passion has been an important research topic in the field of entrepreneurship for the past two decades. Several studies have shown that entrepreneurial passion facilitates the recognition and identification of opportunities and is associated with pride, commitment, energy, and the search for perfection. According to Cardon et al. (2009), entrepreneurial passion plays a crucial role in the creation and management of SMEs. The researchers identified several possible objects of entrepreneurial passion, including the project, the opportunity, the product, and most importantly, "his or her work."

Essential elements for Entrepreneurial success

Certain qualities and skills are required in order to succeed as an entrepreneur. The first key elements to successfully launch one's business are creativity, adaptability and a strong work ethic (Forquesato, 2016). Passion and perseverance are also two important personality traits in order to achieve one's entrepreneurial goals. Research has shown that the emotions and moods individuals encounter, known as affect, have an impact on various cognitive and behavioral aspects. Baron (2008) extended these findings to entrepreneurship and proposed that affect influences multiple facets of entrepreneurs' cognition, thereby playing a crucial role in the entrepreneurial process. Also introduced a theoretical framework to comprehend the significance of affect in key entrepreneurial aspects, such as opportunity recognition and resource acquisition.

TABLE 1. *Contrasting Traits of Individuals with ADHD and Entrepreneurs.*

Character Traits	Person with ADHD	Entrepreneur
Creativity/ Passion	Individuals with ADHD often demonstrate great creativity in problem-solving and approaching situations.	Entrepreneurs need to be creative to find innovative solutions and stand out in the market.
Hyperactivity	Hyperactivity is one of the key symptonm of ADHD, characterized by restlessness, a constant need to move, and difficulty sitting still.	Entrepreneurs are often highly active and energetic, constantly seeking new opportunities and working on multiple projects.
Impulsivity/ Risk-Taking	Individuals with ADHD may exhibit impulsivity, making quick decisions without taking the time to weight all the options.	Entrepreneurs often need to move fast decisions to seize opportunities and respond to challenges in real-time.
Difficulty Focusing	People with ADHD may struggle to concentrate on a specific task for extended periods, easily getting distracted.	Entrepreneurs must be able to focus on long-term goals while managing múltiple aspects of their business.
Resilience	Individuals with ADHD can develop great resilience due to the challenges they face on a daily basis.	Entrepreneurs need to demonstrate resilience in the face of setbacks, failures, and obstacles to continue pursuing their goals.

Source: Authors.

It can conclude that to succeed as an entrepreneur, one must combine creativity, adaptability, a strong work ethic, passion, perseverance, mentorship, market research and continuous learning. By embodying these qualities and following these tips, aspiring entrepreneurs can increase their chances of success. Table 1 compare traits between entrepreneurs and people with ADHD.

Entrepreneurship and ADHD

Lerner et al. (2019) found that people with ADHD are more likely to start their own businesses than people without ADHD. Their study was large, with over 9,000 participants, and it also found that people with ADHD are more likely to have entrepreneurial intentions, meaning that they are thinking about starting their own businesses. This study supports previous research on the link between ADHD and entrepreneurship.

For a long time, we only focus on the negative aspects of ADHD, which are procrastination, inability to concentrate, forgetfulness, distraction and disorganization. Recently, there is evidence that people with ADHD also have a lot of qualities that help entrepreneurship, such as creativity, risk-taking, high energy, being able to multitask and even resilience. According to Sônego et al. (2021), individuals with ADHD exhibit a positive correlation between hyperactive symptoms and a general entrepreneurial orientation. On the other hand, inattention symptoms are associated with less proactivity. Furthermore, ADHD-positive individuals tend to have a higher risk-taking profile, and these characteristics do not have a negative impact on their lives.

Some great entrepreneurs of the 21st century are beginning to publicly admit to their ADHD diagnosis. One example is David Neeleman, a Brazilian-American businessman. He has founded five commercial airlines: Morris Air, WestJet, JetBlue Airways, Azul Brazilian Airlines, and Breeze Airways. For a long time, he believed that he was stupid because of his ADHD and that he would never be able to build anything in his life. But he learned to see the good side of his ADHD and turn it into a strength. His fortune is estimated at 400 million dollars (Gilman, 2021).

The Iowa Gambling Task

The Iowa Gambling Task is the ideal tool for calculating risk-taking among individuals. It is a psychological paradigm used to study decision-making in uncertain and risky situations (Bechara et al., 1994). The task was designed to assess the decision-making process by simulating a gambling environment and examining the behavioral and cognitive tendencies of individuals when faced with choices involving gains and losses (Bechara et al.,1994). Several studies have used IGT in all sort of normal and pathological conditions with humans and animals (Bull et al., 2015; Hultman et al., 2022).

The origins of the Iowa Gambling Task can be traced back to the work of Bechara and his colleagues (1994), who were studying the impact of brain damage on decision-making abilities. They found that some patients with lesions in the Ventromedial Prefrontal Cortex (VPFC) region had difficulty making advantageous decisions in gambling situations (Bechara et al., 1994).

The main aim of the IGT is to explore how individuals make decisions in complex and uncertain environments. The task is designed to assess decision-making in real-life situations, where participants have to choose between different options with probabilistic outcomes. The IGT estimates the ability of individuals to assess the risks and rewards associated with different options, and to learn from experience to maximize their long-term gains (Bechara et al., 2005).

The task is typically performed as follows: participants are presented with four decks of cards. Each deck being associated with varying monetary gains and losses. Two decks are advantageous in the long term, as they generate net gains, while the other two decks are unfavorable in the long term due to the net losses they entail.

Participants are asked to choose cards repeatedly, with the aim of maximizing their monetary gains over a set period of time. As the task progresses, participants receive feedback on their gains and losses to help them adjust their choices. However, participants are not informed of the rules of the task and must learn by trial and error.

In summary, the Iowa Gambling Task is a psychological paradigm used to study decision-making in uncertain and risky situations. It assesses adaptive learning, the initial payoff effect, persistence in choosing the wrong options and the influence of emotional responses on decision-making. The results of the IGT have provided valuable insights into the cognitive and emotional processes involved in decision-making, and have implications for various research areas such as psychology, neuroeconomics and decision-making disorders.

Main Objective

The main objective of this research was to study and understand the relationship between ADHD, as a biological condition, and its impact on entrepreneurial behavior and outcomes. The goal was to shed light on the neurobiological underpinnings of ADHD and how they intersect with entrepreneurial characteristics, such as risk-taking, creativity, and decision making.

Specific objectives

Identify neurobiological mechanisms associated with ADHD that may influence entrepreneurial behavior: This objective involves conducting a comprehensive literature review to explore the neural correlates of ADHD, including brain structures and the neurotransmitter systems. The goal is to understand how these biological factors may be related to and influence entrepreneurial traits.

Examine the manifestation of ADHD traits in entrepreneurs by exploring the role of genetic variations and gene-environment interactions, while considering the influence of environmental factors such as family dynamics, educational experiences, and sociocultural contexts on the entrepreneurial behavior of individuals with ADHD.

Investigate the impact of ADHD symptom on entrepreneurial performance and outcomes to understand the effectiveness and limitations of different ADHD symptom management strategies and their impact on entrepreneurial success.

Understand the decision-making processes in people with ADHD, entrepreneurs, and people without ADHD or entrepreneurial experience in risk and reward contexts by using the Iowa Gambling Task (IGT) to gain insights into the cognitive, emotional, and neurobiological processes that underlie decision-making of these groups of people in complex and uncertain situations.

Research questions (RQ) and hypothesis

- *RQ*1: What level of entrepreneurial behavior may exhibit individuals with Attention Deficit/Hyperactivity Disorder (ADHD) compared to individuals without ADHD? H1: Individuals with ADHD may exhibit higher levels of entrepreneurial traits, such as creativity, risk-taking, and decision-making, compared to individuals without ADHD.
- *RQ*2: How do neurobiological factors associated with ADHD contribute to the success of individuals with ADHD in entrepreneurship, compared to individuals without ADHD? H2: Neurobiological factors associated with ADHD can increase the success of individuals in entrepreneurship, compared to individuals without ADHD.

Material and Methods

Design used

This research employed a semi-experimental design with two key components:

- *Qualitative phase*: Interviews were conducted and later tabulated to identify common and dissimilar patterns in personality traits for quantitative analysis.
- *Quantitative phase*: the Iowa test was used to statistically evaluate the patterns in decision-making of the three groups of people evaluated.

Population and sample

The initial step involved selecting individuals who met one of the following three specific criteria: having ADHD, being entrepreneurs, and a control group without ADHD or entrepreneurial experience. Entrepreneurs are those who identify and

exploit opportunities, make quick decisions under uncertainty, are hard workers determined to achieve their goals, willing to take risks, and "jacks-of-all-trades" who perform a wide range of professional tasks.

Social media platforms were utilized to find these individuals. A story was posted on Instagram with the following message: "If you have ADHD and/or are entrepreneurs, feel free to contact me to assist in my research study." Seven responses were received, comprising four individuals with ADHD and three entrepreneurs. Additionally, three individuals were selected for the control group. Upon establishing contact, Zoom meetings were scheduled.

Ethical considerations

Prior to conducting the private and individual interviews via Zoom, obtaining informed consent from all participants was mandatory. Participants were fully informed about the purpose of the study, the scope of their involvement, and the confidential handling of their data. They were explicitly notified that their participation was voluntary, and they had the right to withdraw at any point without any repercussions. Additionally, participants were assured that their identities would be kept anonymous and that any personal identifying information would be carefully removed or altered in the research output.

The processing of data from the Iowa Gambling Task was carried out with strict adherence to ethical guidelines to protect the participants' privacy and data security. Each participant was assigned a unique identifier code to ensure anonymity, and their actual names or personal details were never linked to their responses during data analysis. The quantitative data collected through the Iowa Gambling Task was securely stored on password-protected servers, accessible only to the research team. The data was used exclusively for academic purposes and was not shared with any external parties or organizations.

Procedures developed

During the Zoom meetings, individual interviews were conducted with each participant. Ten questions were posed to each participant, tailored to their respective profiles. Questions for individuals with ADHD focused on their personal experiences and strategies for living with ADHD, while questions for entrepreneurs were related to their entrepreneurial endeavors and sector-specific challenges. Additionally, as part of the control group, three individuals were interviewed regarding their work and daily life experiences in relation to the research theme.

Following the transcription of the interviews, significant statements were highlighted to gain an overview and facilitate data analysis. Two separate tables were created for ADHD participants and entrepreneurs, respectively, where key ideas were extracted.

After the Zoom interviews, participants were instructed to complete the Iowa Gambling Task. A link to an online platform was provided: https://www.psytoolkit.org/experimentlibrary/igt.html. Participants were directed to click on "Run the demo" and follow the provided instructions:

> In this task, you play a "gambling" game. You need to choose one of 4 buttons (A, B, C or D) with the mouse. Each time, you can win some money, but you may sometimes also have to pay a fee to the bank. After each trial, you need to collect your money, which will adjust your pot of money. You will start with a loan of $2000. There are 100 trials (taking 5 minutes or so). Go on until it stops and see how much you can make on top the loan of $2 000. Press space bar to start. Good luck!".

It was important not to provide additional explanations regarding the Iowa Gambling Task to avoid biasing or influencing the test. Once the test was completed, participants were asked to submit the collected data for analysis. The received data was organized into seven columns, as shown in Table 2.

TABLE 2. *Data Organization from IGT.*

N°	Meaning
1	Reaction time (mouse click)
2	Button clicked (A = l, B = 2, C = 3, D = 4)
3	Presence of a fee to pay (1 = yes, 0 = no)
4	Bank balance before participant's click
5	Bank balance after participant's click
6	Amount won ($50 or $100)
7	Fee to pay ($0, $50, or $250)

Source: Authors.

Techniques and Instruments for the collection of information

All the interviews were recorded for later analysis of the key expressions. These sentences were tabulated and compared between them and with the quantitative results from the Iowa test.

The participant's data was compiled in an Excel spreadsheet. To conduct an in-depth analysis, important data points were highlighted in the Excel spreadsheet. For example, the number of times participants took the risk to draw cards A and B were marked in red. Additionally, amounts below €2 000 and fees of €250 or €50 were color-coded for better visualization. The percentage of high-risk and low-risk choices was calculated.

Data analysis

After analyzing the data, it was compared to the results of the Iowa Gambling Task from the control group consisting of individuals without ADHD or entrepreneurial experience. This comparison aimed to identify potential correlations between these variables.

The obtained results from the Iowa Gambling Task were compared with those of the control group to evaluate any differences in risk-taking performance and account for control factors.

The p-value is used to check the statistical significance of our data. By setting a predetermined significance level (0.05), if the p-value is less than 0.05, it indicates statistically significant results. This will enable us to make informed decisions based on the data analysis.

In summary, the methodology used in this thesis involved participant selection, Zoom meetings, individual interviews, administration of the Iowa Gambling Task, and data analysis. These steps were crucial in gathering the necessary information to investigate the correlation between ADHD and entrepreneurship.

Results

Interviews results

The results of the three types of interviews conducted for this research provide essential insights into the relationship between ADHD and entrepreneurship. Participants with ADHD reported common symptoms such as difficulties with concentration, easy distractibility, organizational challenges, and a constant need for movement. Despite these symptoms, individuals shared personal experiences that highlighted their adaptability and resilience.

A recurring theme in the interviews was the practice of writing everything down. Participants found that keeping detailed notes and lists helped them manage their responsibilities and stay focused. By externalizing their thoughts, they were able to reduce the impact of distractions and maintain a sense of structure. Establishing routines also emerged as a crucial strategy for coping with ADHD symptoms, providing a predictable framework that supported task completion.

A strong desire for personal satisfaction was evident among the interviewees. They expressed a passion for their work. This intrinsic motivation proved to be a powerful force, enabling them to overcome obstacles and persevere in the face of challenges. Additionally, participants described themselves as constantly active, seeking engagement and stimulation to maintain their concentration and productivity.

The connection between ADHD and creativity was a recurring theme throughout the interviews. Participants reported a wealth of connections in their thought processes, enabling them to find innovative solutions to problems. They often generated multiple ideas and approached challenges from unique angles, leveraging their ability to think outside the box. The interviewees believed that their ADHD traits

provided them with a competitive edge in terms of generating novel concepts and adapting to dynamic business environments.

Interestingly, individuals with ADHD exhibited a propensity for taking risks, both professionally and personally. They demonstrated a willingness to embrace uncertainty and navigate uncharted territories. This fearlessness stemmed from their confidence in their problem-solving abilities and their natural inclination to find solutions quickly. Anticipating risks and being prepared to address them was a recurring theme among the participants, highlighting their adaptability in the face of uncertainty.

To remain attentive and focused on tasks or projects, participants recommended a set of strategies. These included writing everything down to clarify ideas and reduce cognitive load, respecting timelines and deadlines, preparing all necessary materials in advance, minimizing environmental distractions, and staying physically active. Engaging in physical activity helped them channel their excess energy and enhance overall concentration and productivity.

Furthermore, according to the interviewed entrepreneurs, the relationship between risk-taking and entrepreneurship is inevitable and significant. They do not experience excessive stress when it comes to taking risks. They are more inclined to see opportunities rather than risks. For them, success in entrepreneurship involves taking calculated risks.

Creativity plays a key role in entrepreneurship. They are capable of bringing innovation, unique ideas, problem-solving skills, and new concepts to the table. Their ability to think creatively gives them a competitive edge in the world of entrepreneurship.

Regarding attention and concentration as an entrepreneur, participants emphasized the importance of organization. As an entrepreneur, it is necessary to manage all aspects of the business. However, they also mentioned being easily distracted in this type of work. To stay focused, they recommend avoiding distractions, establishing priorities, using calendars and to-do lists. They also stress the importance of taking occasional breaks to maintain efficiency.

As for the control group, the main interview responses highlighted similar elements, such as seeking intellectual challenges, driving innovation, finding fulfillment in creating personalized solutions, analyzing and evaluating risks before making decisions, balancing accuracy and innovation, building customer trust, emphasizing organization and mindfulness, fostering a supportive work environment, effective delegation and self-care, utilizing productivity tools, practicing active listening, stimulating creativity by thinking outside the box, promoting a culture of innovation, and designing personalized experiences.

Table 3 highlights the similarities and differences between individuals with ADHD, entrepreneurs, and the control group in terms of risk-taking, attention, and creativity. It shows how individuals with ADHD can bring unique traits and skills to entrepreneurship, while entrepreneurs have specific strategies for managing distractions and maintaining focus. The control group emphasizes organization and analysis rather than creativity.

TABLE 3. *Similarities and differences between individuals with ADHD, entrepreneurs, and the control group.*

Aspect	Individuals with ADHD	Entrepreneurs	Control Group
Risk-taking	High propensity for risktaking, confidence in their ability to solve problems quickly, willingness to embrace uncertainty and navigate uncharted territories.	Inherent risk-taking in entrepreneurship, evaluating risks before making decisions, focusing on opportunities rather than risks.	Seeking a balance between precision and innovation, analyzing and evaluating risks before making decisions.
Attention	Difficulties with concentration, distractibility, organizational challenges, constant need for movement. Strategies such as writing everything down, respecting timelines, minimizing distractions, and staying physically active to maintain focos.	Need to stay focused on tasks and projects, challenges with distractions in entrepreneurial work. Strategies such as avoiding distractions, prioritizing tasks, using calendars and to-do lists, and taking occasional breaks.	Importance of organization in entrepreneurship, challenges with distractions in entrepreneurial work. Similar strategies to entrepreneurs, such as prioritizing tasks, using calendars and to-do lists, and taking occasional breaks. Focus on precision rather than innovation.
Creativity	Ability to think creatively, generation of multiple ideas, approaching challenges from unique angles using divergent thinking to find innovative solutions.	Bringing innovation, unique ideas, problem-solving skills, and new concepts to the table. Utilizing creative thinking as a competitive advantage in entrepreneurship.	Focus on analysis and evaluation rather than creative thinking. Promoting a culture of innovation and designing personalized experiences.

Source: Authors.

IOWA GAMBLING TASK RESULTS

Participants with ADHD

TABLE 4. *IGT responses from participants with ADHD.*

Subject No.	Total cards picked	Cards picked from hight risky decks	Cards picked from low risky decks	High risk decision level	Low risk decision level	Balance at the end of the task	Money "earned" in the task	Time spent in the task (min)
1	100	20	80	15%	85%	3 250 €	1.250 €	24.5
2	100	52	48	51%	49%	1 450 €	–550 €	15.9
3	100	58	42	62%	38%	1 800€	–200 €	14.3
4	100	44	56	42%	58%	2 200 €	200 €	13.2

Source: Authors.

The data collected during the IGT from participants with ADHD are summarized in the Table 4.

The first observation is the variation in results between participants. Some achieved a high final score, while others had less favorable results. This suggests variability in risk-taking behavior among individuals with ADHD.

Looking at the fee decisions, we can see that participants opted for a fee of 250 in some cases, but preferred a fee of 50 in others. This indicates a certain ambivalence about the level of risk chosen by participants with ADHD. We know that the 250 fee offers potentially higher rewards, but also higher risk. Fees of 50, on the other hand, present a lower risk but offer more modest rewards.

In terms of risk categories, the results reveal a variable preference for high- or low-risk options. Some participants showed a preference for high-risk choices, while others favored low-risk options. These results illustrate the divergence in risk-taking behavior among individuals with ADHD.

The results of this study highlight the importance of examining risk-taking in individuals with ADHD. The variations observed in final outcomes, cost choices and risk preferences highlight the complexity of decision-making behaviors in these individuals.

These findings are consistent with our previous theories suggesting that people with ADHD may exhibit impulsive tendencies and difficulty evaluating the long-term consequences of their actions. The ambivalence observed in cost choices and risk preferences may reflect the challenges faced by individuals with ADHD when weighing potential risks and benefits.

However, it should be noted that this study has certain limitations. The sample size is relatively small, which limits the generalizability of the results. In addition, other factors such as age, gender and ADHD severity could influence risk-taking behaviors and should be considered in future research.

Participants with entrepreneurship

The data collected during the IGT from participants with entrepreneurship are summarized in the Table 5.

TABLE 5. *IGT responses from participants with entrepreneurship.*

Subject No.	Total cards picked	Cards picked from hight risky decks	Cards picked from low risky decks	High risk decision level	Low risk decision level	Balance at the end of the task	Money "earned" in the task	Time spent in the task (min)
5	100	70	30	69%	31%	950€	–1 050€	29.2
6	100	30	70	30%	70%	2 950€	950€	13.0
7	100	2	98	2%	98%	4 400 €	2 400€	9.8

Source: Authors.

Analysis of the data reveals some interesting trends in entrepreneurial risk-taking. Looking at the percentages of high-risk and low-risk choices, we observe significant variations. Entrepreneurs opted for high-risk choices in proportions ranging from 2% to 69%. This indicates a variable propensity to make risky decisions, which can be attributed to their daring nature and willingness to seize opportunities.

On the other hand, low-risk choices were favored by between 31% and 98%. This shows that entrepreneurs are also aware of the need to limit risk and protect their investments. They make decisions calculated to minimize potential losses and maximize gains.

Furthermore, the financial performance of contractors, as measured by the final amount obtained, varies considerably. Final amounts ranged from €950 to €4 400, reflecting the varying results of decisions made during the task. This variation suggests that risk-taking may have a direct impact on the gains accumulated by entrepreneurs.

The results of this analysis highlight the intrinsically risky nature of the entrepreneurial spirit. Entrepreneurs are willing to take calculated risks to seize opportunities and achieve their goals. However, they are also aware of the need to limit risk and make prudent decisions to protect their investments.

Control group

The data collected during the IGT from participants of the control group are summarized in the Table 6.

TABLE 6. *IGT responses from participants of the control group.*

Subject No.	Total cards picked	Cards picked from hight risky decks	Cards picked from low risky decks	High risk decision level	Low risk decision level	Balance at the end of the task	Money "earned" in the task	Time spent in the task (min)
8	100	24	76	25%	75%	3 350€	1 350€	13.0
9	100	6	94	3%	97%	4 050€	2 050€	45.2
10	100	62	38	52%	48%	900€	–1 100€	23.6

Source: Authors.

Looking at the percentages of high-risk and low-risk choices, we observe some variability. Participants opted for high-risk choices in proportions ranging from 3% to 52%. This indicates a variable tendency to make risky decisions, despite the associated potential negative consequences.

On the other hand, low-risk choices were preferred in a proportion ranging from 48% to 97%, also suggesting a certain prudence in risk management. Furthermore, the results show significant differences in participants' financial performance, as measured by the final amount obtained. Randomly selected

individuals achieved variable results, ranging from €900 to €4 050. This variation suggests that risk-taking may have a direct impact on the gains accumulated during the task. It is possible that participants who demonstrated a higher propensity to take risks experienced greater fluctuations in their financial results.

The results of this analysis highlight the existence of individual differences in risk-taking in randomly selected individuals, without any pathology. Although the tendency to make risky decisions varied, participants also showed a certain caution in opting for low-risk choices. These observations suggest that risk-taking is a complex process influenced by a combination of individual and contextual factors. Understanding these mechanisms is essential to inform decision-making in uncertain situations, whether in gambling, investment or other areas of daily life.

p-value

When comparing the means of the ADHD and Entrepreneur groups, a bilateral p-value of 0.743 was found (Table 7). Since the p-value is greater than the alpha value of 0.05 (5%), we cannot reject the null hypothesis. This means that there is not enough evidence to claim that the means of the ADHD and Entrepreneur groups differ significantly.

TABLE 7. *Test of equality of expectations: two observations with different variances ADHD & Entrepreneurl.*

	ADHD	Entrepreneur
Mean	0.425	0.347
Variance	0.040	0.112
Observations	4	3
Hypothetical difference of means	0	
Degree of freedom	3	
t statistic	0.359	
P(T<=t) one-tailed	0.372	
Critical value of t (one-sided)	2353	
P(T<=t) two-tailed	0.743	
Critical value of t (two-tailed)	3.182	

Source: Authors.

In the second test of equality of means between the ADHD and Control groups, the bilateral p-value is 0.413 (Table 8). Since this p-value is also greater than the alpha value of 0.05 (5%), we cannot reject the null hypothesis.

TABLE 8. *Test of equality of expectations: two observations with different variances ADHD & Control Group*

	ADHD	Entrepreneur
Mean	0.425	0.267
Variance	0.040	0.060
Observations	4	3
Hypothetical difference of means	0	
Degree of freedom	4	
t statistic	0.912	
P(T<=t) one-tailed	0.207	
Critical value of t (one-sided)	2.132	
P(T<=t) two-tailed	0.413	
Critical value of t (two-tailed)	2.776	

Source: Authors.

This indicates that there is not enough evidence to suggest that the means of the ADHD and Control groups differ significantly.

In conclusion, in both tests, the hypotheses of equality of means are not significant at a significance level of 5% (alpha value of 0.05).

DISCUSSION

The Iowa Gambling Task (IGT) provided valuable insights into risk-taking behavior in different populations as mentioned by Bechara et al. (1994). Analysis of data collected from participants with ADHD, entrepreneurs and randomly selected individuals highlights the complexity of decision-making and risk preferences in these groups.

Participants with ADHD showed variability in their risk-taking behaviors, as evidenced by variations in their final scores, agreeing with what was expressed by Khalid and Sekiguchi (2018). The ambivalence observed in their fee choices suggests a difficulty in evaluating and balancing potential risks and rewards. This confirms earlier theories suggesting impulsivity and difficulties in assessing long-term consequences in people with ADHD (Shaw et al., 2012).

Entrepreneurs, on the other hand, exhibited a more diverse range of risk-taking behaviors. The proportion of high-risk choices varied considerably among them, reflecting their bold nature and willingness to seize opportunities. At the same time, they were conscious of limiting risk and protecting their investments by opting for low-risk choices in certain situations. Variation in financial performance also highlights the impact of risk-taking on their results, as pointed out by Davis (2010).

In the case of randomly selected individuals without pathology, a similar pattern of variability in risk-taking behavior emerged. The percentages of high-risk and low-risk choices varied, indicating different tendencies among individuals.

Financial performance also showed considerable variation, suggesting a direct influence of risk- taking on gains achieved during the task, as reported by Bull et al. (2015).

Overall, these results highlight the complexity of risk-taking behavior and the importance of understanding individual and contextual factors in decision-making processes, as described by Antoncic et al. (2018). The results highlight the need for tailored interventions and support systems that take into account the unique risk profiles of different populations.

However, it is important to recognize the limitations of the study, such as the relatively small sample size and the absence of certain demographic and clinical factors that may influence risk-taking behavior.

Conclusions

Based on the available data and analyses, the results of the study provide insights regarding the two hypotheses formulated. Hypothesis 1 posits that individuals with ADHD exhibit higher levels of entrepreneurial traits such as creativity, risk-taking propensity, and opportunity recognition compared to individuals without ADHD. The study confirms this hypothesis by demonstrating that individuals with ADHD display high levels of creativity, marked passion, and a propensity for risk-taking, which align with the characteristics sought in entrepreneurship. Additionally, the study reveals similar patterns of risk-taking and creative thinking in the control group, suggesting that these traits are not exclusive to individuals with ADHD or entrepreneurs but may also be present in others.

Regarding Hypothesis 2, which suggests that neurobiological factors associated with ADHD will influence the success of individuals in entrepreneurship compared to individuals without ADHD, the available data does not directly address this hypothesis. While the study provides information on entrepreneurial traits and risk-taking propensity among individuals with ADHD, entrepreneurs, and a control group, it does not specifically examine the direct influence of neurobiological factors on success in entrepreneurship. Therefore, it is not possible to definitively confirm or refute Hypothesis 2 based on the available data.

It is important to note that ADHD is a complex and multifactorial disorder, and its exact causes remain unknown. The study acknowledges this complexity and highlights the heterogeneity of ADHD presentations, indicating that individuals with ADHD can exhibit different symptom profiles and respond differently to interventions. This diversity makes it challenging to identify a singular cause, emphasizing the need for ongoing research to deepen our understanding of this disorder.

Furthermore, the study underscores the importance of considering individual and contextual factors in decision-making processes, including the neurobiological factors associated with ADHD. Although the available data did not directly examine the influence of these factors on success in entrepreneurship, it highlights the significance of understanding the complex influences involved in decision-making, particularly in the context of entrepreneurship.

Thus, based on the available data, it is not possible to definitively confirm or refute Hypothesis 2 regarding the direct influence of neurobiological factors on the success of individuals in entrepreneurship. However, the study confirms the existence of entrepreneurial traits in individuals with ADHD and highlights the importance of understanding the multiple and complex influences that shape entrepreneurial behavior.

Overall, this study contributes to our understanding of the relationships between ADHD, entrepreneurial traits, and neurobiological factors. It emphasizes the importance of considering individual differences and specific contexts when evaluating entrepreneurial behavior in individuals with ADHD. Future research could further explore these questions by directly examining neurobiological factors and their impact on entrepreneurship success while taking into account the limitations of the current study, such as the relatively small sample size and the absence of certain demographic and clinical variables. A better understanding of these aspects would help develop tailored interventions and improved support systems that consider the specific risk profiles of different populations.

Conflicts of Interest

Authors reports no conflicts of interest to report in relation to this study.

Contributor Roles

Manon Muûls: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Visualization, Writing – original draft.
Rubén Carvajal: Conceptualization, Methodology, Software, Supervision, Validation, Visualization, Writing – review & editing.

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