

# **Personality Traits of Entrepreneurs – a Neuroscientific Approach**

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## **Project A**

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## **Statutory Declaration**

We hereby certify this paper is our own work and contains no material that has been submitted previously, in whole or in part, in respect of any other academic award or any other degree. To the best of our knowledge all used sources, information and quotations are referenced as such.

Villingen-Schwenningen, 29.06.2021

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## **Abstract**

The purpose of the study is to identify the profile of a start-up founder. In particular, it investigates whether there are some determined personality characteristics which are common among start-up founders. The present paper is questioning which neuropsychological traits and brain areas are responsible for entrepreneurial behavior. Therefore, the main focus was on the correlation between brain areas and individual attitudes or behaviors. After explaining the related basics about the human brain, it is important to locate some key tasks or activities in specific brain regions. Neuroimaging tools such as fMRI and EEG are particularly helpful to explain the reason for specific behaviors because they determine the presence of connection between cognitive processes and brain areas. In the present paper, EEG will be taken into consideration since this method can provide some practical insight into differences between entrepreneurs and non-entrepreneurs. The most important characteristics of entrepreneurs are defined in order to show theoretically whether there is a fundamental difference between entrepreneurs and non-entrepreneurs on a neuropsychological level. Even though there are elements which are emphasized in the personality of start-up founders, further research is required to prove that these aspects determine indisputably entrepreneurial behavior.

### **Keywords:**

Start-up founder, Neuro-entrepreneurship, Entrepreneurial characteristics, EEG, Opportunity identification, Risk-taking

### **Highlights of the Paper:**

- People with an entrepreneurial background may possess certain traits in a more distinctive form than people without a non-entrepreneurial background.
- The Cerebrum and the frontal lobe seem to be the most responsible part of the brain to pursue entrepreneurial intentions.
- It has not been proven that certain character traits of entrepreneurs that are more pronounced compared to non-entrepreneurs automatically qualify an entrepreneur.

## Table of Content

<b>Statutory Declaration</b>	<b>2</b>
<b>Abstract</b>	<b>3</b>
<b>List of Figures</b>	<b>VI</b>
<b>List of Abbreviations</b>	<b>VII</b>
<b>1. Introduction</b>	<b>1</b>
1.1. Relevance of the topic	1
1.2. Objective of the work	2
1.3. Methodology and structure	2
<b>2. Definitions</b>	<b>4</b>
2.1. Start-ups	4
2.2. Entrepreneurs	5
2.3. Entrepreneurial Characteristics	6
2.4. Entrepreneurial Ecosystem	8
<b>3. Human Brain</b>	<b>10</b>
<b>4. Neuroimaging Methods</b>	<b>14</b>
4.1. General remarks	14
4.2. EEG	14
<b>5. Entrepreneurial Characteristics and Cognitive Capacities</b>	<b>17</b>
5.1. Opportunity Identification	18
5.2. Risk-taking	21
5.3. Proactivity	24
5.4. Self-Efficacy	25
5.5. Motivation	26
5.6. Vision	27
5.7. Passion	28

<b>5.8. Creativity</b>	<b>29</b>
<b>5.9. Problem-Solving &amp; Decision-Making</b>	<b>30</b>
<b>5.10. Resilience</b>	<b>31</b>
<b>5.11. Assertiveness</b>	<b>32</b>
<b>5.12. Conscientiousness &amp; Trust</b>	<b>32</b>
<b>5.13. Openness to change</b>	<b>33</b>
<b>5.14. Neuroticism</b>	<b>34</b>
<b>5.15. Altruism &amp; Modesty</b>	<b>34</b>
<b>6. Conclusion</b>	<b>35</b>
<b>7. Limitations</b>	<b>37</b>
<b>8. Outlook</b>	<b>38</b>
<b>Bibliography</b>	<b>39</b>
<b>Appendix 1 - The human brain</b>	<b>52</b>
<b>Appendix 2 - Relevant Information about fMRI</b>	<b>53</b>
<b>Appendix 3 - Characteristic traits of Entrepreneurs &amp; Neuroimaging Methods</b>	<b>55</b>

## List of Figures

Figure 1: Big Five Personality Dimensions (Rothmann & Coetzer, 2003) .....	7
Figure 2: Functions of brain lobes (Cloverdale Rehab Clinic, 2020) .....	12
Figure 3: Characteristic traits of Entrepreneurs & Neuroimaging Methods .....	18
Figure 4: CBM of non-entrepreneurs during the search of opportunities (Zaro et al. 2016) .....	21
Figure 5: CBM of entrepreneurs during the search of opportunities (Zaro et al. 2016) .....	21
Figure 6: CBM of non-entrepreneurs during the process of risk-taking (Zaro et al. 2016) ..	23
Figure 7: CBM of entrepreneurs during the process of risk-taking (Zaro et al. 2016) .....	23
Figure 8: Skills connected to problem-solving (Open Education Resource, 2020) .....	30

**List of Abbreviations**

CBM	Cognitive Brain Mapping
CD-RISC	Connor-Davidson Resilience Scale
EEG	Electroencephalography
fMRI	Functional Magnetic Resonance Imaging
HFU	Hochschule Furtwangen
iEEG	Intracranial Electroencephalography
MAP-Test	Measuring and Assessing individual Potential – Test
MRI	Magnetic Resonance Imaging
OPERAS	Overall Personality Assessment Scale
PCI	Proactive Coping Inventory
RAS	Rathus Assertiveness Schedule
SGP-Test	Startup founder profile - Test

## 1. Introduction

„Risk more than others think is safe. Dream more than others think is practical.“

– Howard Schultz

But is it really the case that the characteristic of being a person who is willing to take risks is decisive for entrepreneurs and their success? The following research will take a closer look at the extent to which character traits and personality traits can be held responsible for this and much else. People try to predict their own future actions and outcomes, to create growth and a successful future, for which the exploitation of knowledge (Audretsch et al., 2016) and the personality of the individual (Ratzinger et al., 2017) are key components. Start-ups, together with their founders, have emerged as one of the most powerful engines of economic growth in the last decade. They found new markets and opportunities that transformed the way in which business has been experienced. Smart innovation and pure brilliance left various industries behind (Kalogiannidis & Chatzitheodoridis, 2021). As entrepreneurial thinking and action is becoming an increasingly important factor for organizational success, the entrepreneurial passion to create it is a key aspiration for the associated shaping of the future, which is significantly influenced by a persons' neuropsychological characteristics (Obschonka et al., 2018).

### 1.1. Relevance of the topic

There is a lot of existing literature about the multiple concepts and methods related to the analysis of entrepreneurial characteristics (Kerr et al., 2017). In recent years, cognitive neuroscience has become an inspiration for various research areas such as consumer research, financial and organizational behavior, as well as entrepreneurship. The focus in the area of neuro-entrepreneurship is on topics such as unconscious processes in entrepreneurial behavior and characteristics, but the field is still very under-researched (Bentzen, 2018). There are various different personality traits that lead a person to develop an entrepreneurial intention (Karabulut, 2016). Cognitive neuroscience can

contribute in many ways to the field of entrepreneurial behavior, the composition of personality traits and characteristics of start-up founders. Simultaneously, it is important to note that neuro-entrepreneurship will not be a game changer in the field of entrepreneurship. But it is an important source of new inspiration and an opportunity to explore new grounds in entrepreneurship research, because it embodies a field that has not been given enough prominence so far - the biological aspect (Bentzen, 2018).

### **1.2. Objective of the work**

The purpose of this work is to find out if there is a neurological correlation between the brain and entrepreneurial activities by start-up personalities. A focus was laid on the internal factors, their different elements and the possible operationalization approaches of these personality traits. The current state of the art in the field of neuro-entrepreneurship has various research gaps when it comes to the interrelationships with entrepreneurship (Day et al., 2017). This paper summarizes the current state of research on neurological correlations of start-up personalities and entrepreneurial characteristics and personality traits, with a strong emphasis on objectivity. The research question of this paper is: Which neuro-psychological characteristics & parts of the brain are responsible for entrepreneurial activities?

### **1.3. Methodology and structure**

Exploring and relating knowledge is the fundamental component of all academic research activities, independently of the discipline. Taking into account previous, relevant literature is essential for all research disciplines. This research describes previous and recent research, to map and evaluate the research area of entrepreneurship and neuropsychology (Snyder, 2019).

The aim of this study is to establish the current state of research to find out if there is a neurological link between the brain and entrepreneurial activities of start-up personalities. To do so, theory will be evaluated to investigate the effect of the relationship between the human brain and entrepreneurial activities and related personality traits. In order to answer the research question, a literature

research was carried out. For certain types of research projects involving national or international comparisons of different personalities and characteristics, as in the present case, the secondary data are considered sufficient to answer the research question at hand and to achieve the objectives set (Saunders, Lewis, & Thornhill, 2019). Literature review is useful when the aim is to provide an overview of a particular topic or research problem (Snyder, 2019). According to the source, secondary data can be divided into three main subgroups: document based, survey based and those compiled from multiple sourcing (Saunders, Lewis, & Thornhill, 2019). This paper relies on multiple sourcing data and document based sources which can be accessed online, such as books, journals, articles and newspapers (Saunders, Lewis, & Thornhill, 2019).

This research will focus on identifying the relationship between entrepreneurial traits, brain activities and operationalization methods of the identified entrepreneurial traits with a focus on the neuroimaging method EEG. A semi-systematic review was chosen as the method for the present work. Beyond the purpose of providing an overview of a subject, a semi-systematic review often examines the ways in which research within a selected field has evolved over time or how a given subject has transcended across research traditions. Semi-systematic reviews aim to identify themes and theoretical perspectives or joint concerns within a discipline in order to pinpoint components of a theoretical concept. In addition, they are used to further synthesize the state of the art and set an agenda for continued research, as in this case (Snyder, 2019). In general, semi-systematic reviews try to both identify and comprehend all their prospectively relevant research streams that have implications for the topic under consideration, and then use meta-narratives to synthesize them, rather than measuring effect size (Wong, 2013). This approach to review is commonly followed by a qualitative analysis (Snyder, 2019), which will in this case, be carried out by Prof. Dr. Eva Kirner and Prof. Dr. Kai-Markus Müller from HFU University. The focus of this subsequent project will be to measure brain waves of entrepreneurial active people and compare them to see whether one can find a neurological proof if there is a significant difference in between people with an entrepreneurial background and people with a non-entrepreneurial background.

As far as the structure of this paper is concerned, the most important basic terms such as start-up, entrepreneur and entrepreneurial ecosystem are first described. The next chapter deals with the structure of the brain and its neurocognitive components. Finally, one of the most important neuroimaging methods, the EEG, is explained before entrepreneurial traits are broken down and, if possible, explained in detail with the brain regions involved and their operationalization methods.

## **2. Definitions**

### **2.1. Start-ups**

Although in the past decade an increasing number of academics have attempted to capture and describe the characteristics of the start-up movement, there is no general agreement between scientists, business support institutions or entrepreneurs themselves on how to define the term “start-up” (Breschi et al., 2018). Originally, the word “start-up” was defined as “any form of business in its early stage of development”, but the concept started to be more specific during the 1970s, when the contribution of technology to start-up was added to the original definition (Skala, 2018).

Steve Blank explained that “a start-up is a temporary organization created to look for a repeatable and scalable business model”. According to Blank, start-ups can be identified based on three criteria: goals, function and funding structure (Skala, 2018). Joseph Schumpeter was the first one linking the field of innovation to entrepreneurship (Schumpeter, 1942). Technology is implicitly present when Blank mentions “scalability” because automation and innovation can help start-ups to adapt the business to a change in demand (Skala, 2018).

Besides the definition of a start-up being an enterprise in a very early stage of his lifecycle (Breschi et al., 2018), Skala developed her own definition. It divides the life cycle of a start-up into three basic stages: initial, expansion and maturity stage. In the first stage, the organization has limited resources but identifies a market need and consequently offers a solution. Start-ups are characterized by an innovative and unverified business model that offers new solutions and does

not merely replicate existing organizations. Reaching the next level is achieved by hyper-scalability through the implementation of precise technology. In the end, successful startups experience rapid growth, first in customers, then in revenue, and finally in enterprise value (Skala, 2018).

## **2.2. Entrepreneurs**

For thousands of years, humans have been breaking traditional ways of living or doing in order to reach higher standards of living. As a result, these changes have brought major contributions to the entire planet and humankind in terms of social, economic, technological or more recently, environmental circumstances. Each era held its own style of innovation and ideas, and the later in history they came, the more sophisticated they got. New proposals are often the results of two things: the application of knowledge and the inventor's background and commitment to an idea. Innovation means both success and failure, and can bring either a high price or great personal and financial reward (Heyworth-Dunne, 2020). Today, the concept of risk-taking for co-development is broader, but also more focused on technological or business skills and social sciences. They are meant to either revolutionize or offer breakthrough ideas that capture consumer attention and encourage a shift in focus to consumer demand (Santos & Eisenhardt, 2009).

As a result of the positive outcomes of entrepreneurial activity in the last years, academics have tried to distinguish a specific set of characteristics to describe the entrepreneurial profile. In general an entrepreneur is considered as an individual who engages in the process of value creation by deploying and assembling a set of required resources to take advantage of an opportunity (Stevenson et al., 1989; Kuratko, 2016).

It is important to mention that since the focus of this research is on entrepreneurial activity, this study does not distinguish between an entrepreneur and a start-up founder. While in the literature, an entrepreneur has been identified only with creating and seizing opportunities (Rakib et al., 2020), he or she could try to improve, adapt, develop, invent, or found a product, service, or organization (Korpysa, 2020). While on the other hand, a start-up founder could be identified

as a hallmark of entrepreneurship by working to create something new that essentially launches a burgeoning industry (Zuzul & Tripsas, 2020). Either way, whether entrepreneurs or start-up founders, rather than analyzing external factors, this research seeks to use a neuroscience approach to discuss what is going on in the minds of these individuals that promotes entrepreneurial activity.

### **2.3. Entrepreneurial Characteristics**

Many different characteristics are within these entrepreneurs and among others; opportunity identification (Tuğba, 2016), self-efficacy (Pekkala et al., 2017), good verbal skills (Sting, 2019) or the profound driver of passion that boosts proactivity, creativity, risk-taking, aspiration, resilience and persistence (Cardon et al., 2009). Passion is another aspect to consider because it is the basis for many other factors such as proactivity, risk-taking, aspiration, resilience, and persistence (Obschonka et al., 2019). With different combinations of skills and traits, those who rise through difficult times and unstable economies would be seen as particularly resilient entrepreneurs (Heyworth-Dunne, 2020)

A lot of studies in the context of research about the entrepreneurial mindset explored the characteristics of individuals, teams, organizations and environments that influence the entrepreneurial thinking process and their outcomes of it (Shepherd & Patzelt, 2018). One of the studies is Project Dali. The study took place in 2019 and was initiated by Swedish incubators named Sting, Umeå Biotech and researchers from the Karolinska Institute in Sweden. During the project they used four different tools to find common denominators on a selection of Swedish entrepreneurs to show their characteristics. The tests were performed on entrepreneurs and on a general population of individuals with a non-entrepreneurial context. These tools were qualitative interviews with the individuals and the following tests: Matrigma-Test, which is a tool for measuring talent, associated with IQ-level of individuals. The MAP-Test for measuring and assessing individual potential, based on the five-factor-model. The Game Intelligence Test, which measures abilities that regulate brain information, processing, thoughts and emotions, based on executive functions. And finally the SGP-test, which deals with the start-up founder profile (Sting, 2019).

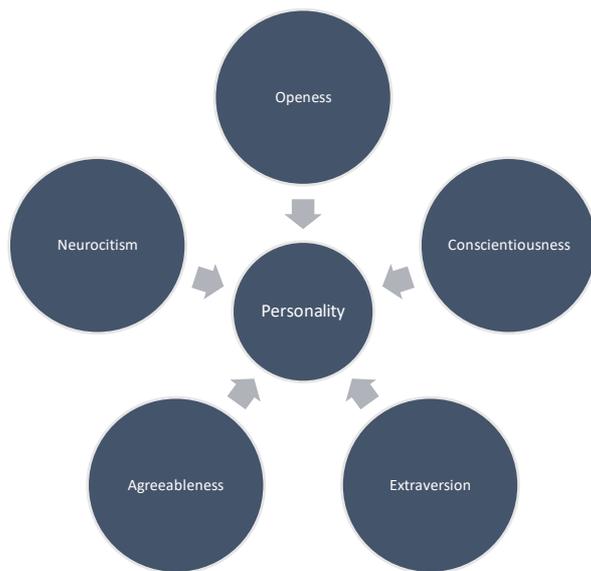


Figure 1: Big Five Personality Dimensions (Rothmann & Coetzer, 2003)

The mentioned five-factor-model is shown in Figure 1. It tries to define personality and personality traits adopting a multidimensional approach (Pekkala et al., 2017). The model provides a framework for organizing patterns of affect, behavior and cognition (Sun et al., 2018). According to the five-factor-model, there are five main personality traits. The first trait is openness, it describes how an individual's experiential and mental life looks like. Secondly, the framework covers conscientiousness: the socially prescribed impulse control facilitates goal-oriented behavior and the task-oriented one. The third trait is extraversion, which includes many different characteristics such as assertiveness, social activity and positive emotionality. Then, agreeableness describes the orientation towards others, for instance it involves trust and modesty, altruism and tender-mindedness. Finally, the model also includes neuroticism: this trait opposes emotional stability with negative feelings such as anxiety, nervousness, sadness and tension (Pekkala et al., 2017).

As a first result they discovered that only for the Game Intelligence tests, the results of entrepreneurs were considerably different from the general population. This particularly applies to the more complex cognitive functions and the creative aspects. Generally, cognitive functions show the individual's ability to adapt logically, as well as the ability to be dynamic, creative and focused. To find out which neuropsychological characteristics and parts of the brain are responsible

for entrepreneurial activities it must be clarified if there are existing differences between the general population and entrepreneurs. Therefore an underlying question is if the differences shown inside this study could mean that they are responsible for resulting brain activities (Sting, 2019).

The most important findings of the former mentioned study will be summarized in the following paragraph. The entrepreneurial group was especially good in processing more complex information compared to the general population. Besides, they had generically higher scores at basic cognitive functions like scanning, cognitive flexibility, short-term memory and the speed of processing. Among all, the creative parts were the most excellent ones. The entrepreneurial group was especially good at conceptualizing tasks, as functioning as a whole and creating together. Another strong ability was rational, strategic and abstract thinking, for example realizing important logical relationships and the ability to deal with complex concepts and contexts. Other important roles play cognitive flexibility, like switching in between different topics without losing focus on the important things and a high verbal ability as well as the ability of sustained attention and endurance. All of them are especially important in dynamic contexts and demanding situations. The majority of the entrepreneurial group had peak abilities within complex thinking and a balanced self-awareness. Additional to that they had individual differences in cognitive capacity, the biggest difference was in impulse control. The main finding of the study is that there is no universal entrepreneurial profile, but there are existing personality traits or characteristics that characterize entrepreneurs who build successful companies (Sting, 2019). It can be concluded that the start-up founder must have a clear vision and be aware that continuous innovation is necessary to grow the business. There are also other elements, such as self-efficacy, receiving support and finding a reliable co-founder, which leads us to the next chapter, dealing with the entrepreneurial ecosystem (Dessyana & Prihatin Dwi Riyanti, 2019).

## **2.4. Entrepreneurial Ecosystem**

While talking about external factors that influence entrepreneurial activities by individuals, one often hears the term Entrepreneurial Ecosystem (Makecki,

2018). As entrepreneurs and start-up personalities are rising exponentially around the globe, there is an increasing amount of establishment of environments, that are trying to increase the success of newly founded ventures, which also influence the behavior and the success of entrepreneurs participating inside these ecosystems (Audretsch et al., 2019).

The entrepreneurial behavior is being influenced by its individual environment, which is why we have to take into consideration society mechanisms, different institutions or networks as well as cultures that can have a supportive or non-supportive function on its entrepreneurial behavior. Entrepreneurial ecosystems mostly have similarities with industrial clusters or innovation systems. In these two mentioned frameworks entrepreneurs are also present, but there is no focus on them. Until now there is not a widely distributed definition for it, but the notion of the term entrepreneurial ecosystem highlights “the combination or interaction of elements [...] producing shared cultural values that support entrepreneurial activity” (Makecki, 2018). An entrepreneurial ecosystem should generate value for the players and society involved in it as well as having the responsibility to distribute the value among the players. Therefore, economic and technological dimensions are responsible for the creation of value, while the societal dimension works on the distribution of the generated value (Audretsch et al., 2019).

Influential factors on start-up founders are impacts from culture, family, networks and political systems, which can be really different depending on the place individuals are born and raised (Trost et al., 2015). Different literature has various names for the system around start-up founders, for all of them apply: the actors are interdependent. These external factors consist of different stakeholders, each of them having a different connection to the start-up founder.

One stakeholder is the founder's family and friends. In many cases, the family can have a high impact in terms of evaluating a potential founder's idea. The environment of friends can be divided into close friends and a wider circle of acquaintances (Pott & Pott, 2015). Investors as well as banks also play a central role in a founder's environment. Above all, they are a possible source of funds, and the potential start-up project stands or falls with them. Moreover, the public is the "space" in which the company is perceived by individuals. The media plays

a major role in public perception, as well as the state a founder's situational environment is placed in (Troost et al., 2015). The state also influences the basic attitude towards starting a business in the respective country: if a start-up is viewed positively, it promotes the initiative of young people to start a business. There are various other stakeholders like, e.g. employees, partners, suppliers, customers and competitors. Due to the fact that the focus of this work lays on the neurological background these will not be examined in detail (Pott & Pott, 2015). External factors also influence the correlation between the brain and entrepreneurial activities. The human brain, welfare, and one's mental health is influenced by environmental exposures. The focus lies on resilience and the ability of the human brain to adapt to and successfully cope with adverse environmental influences. Convergent neural systems of risk and resilience and their relation to the social environment of a developing individual play a crucial role. Various other factors have enduring effects on the structure and function of the neural circuits inside one's body such as, social support in childhood of parents and caregivers, social support and exclusion in adulthood and influences of the environment or the place of residence. The latter can be divided into the following categories: psychosocial stressors, air pollution and nature experience. Social-environmental components vary in duration, time and structure. The outcoming effect of them tends to involve key structures inside the brain, closely linked to the amygdala, hippocampus and prefrontal regions, which are mostly responsible for the stress response (Troost et al., 2015). An illustration of this is when one attempts to perform a free action, as one does so, he or she is influenced by sensory information (Charles & Haggard, 2020).

### **3. Human Brain**

Since this research aims to find out whether there is a neurological link between the brain and entrepreneurial activities, the following chapter is dedicated to the human brain and its main functions and components (Faller & Schünke, 2012). The human brain weighs about 1.5 kilogram. Due to this brain size, humans have an encephalization quotient of 7.4, which is the highest encephalization quotient throughout the animal kingdom. The encephalization quotient describes the

relation between the actual brain size and the brain size that should be expected with the respective body weight (Herculano-Houzel, 2009; Seth, 2019).

The cerebral tissue of the human brain consists of gray and white matter, which is composed of neurons and supporting glial cells. What is perceived as gray matter is the cell body of neurons, the so-called soma. The white matter consists of the nerve cell extensions together with the glial cells (Carter, 2019; Trepel, 2009).

The human brain can be divided into six main areas: the **Telencephalon**, the **Diencephalon**, the **Mesencephalon**, the **Pons**, the **Cerebellum** and the **Extended Mark**. These areas can then be divided into different sections, where each section is assigned to a different function. Additionally, the brain also contains the limbic system, which has no assigned place in the human brain, but takes place in different parts of the brain. It is involved in learning mechanisms, creation of memories, feelings and emotions as well as the motivation of individuals. It enables us to inhibit instinctive reactions. Also, the limbic system assists in adjusting our behavior dynamically to our changing environment (Faller & Schünke, 2012). An overview with a summary about the following parts of the brain and their functions can be found in Appendix 1.

The **Telencephalon** makes up about 80% of the human brain. It is composed of Cerebrum, Cerebral Cortex and Basal Ganglia. The Cerebrum processes excitation coming from the sensory organs, as well as it is involved in learning and planning processes, memory, ethical and moral ideas. The right hemisphere is considered to be the visual hemisphere and is responsible for imagination, colors, spatial imagination, patterns, recognition and abstract thinking, whereas the left hemisphere is considered to be the hemisphere for logical thinking. It is responsible for logic, numbers, language, problem evaluation and lists. So, the left hemisphere focuses more on details, while the right hemisphere focuses on the overall picture. Additionally to the partition in the two hemispheres, the Cerebrum can be divided into four lobes: the frontal lobe, the parietal lobe, the occipital lobe and the temporal lobe (Faller & Schünke, 2012).

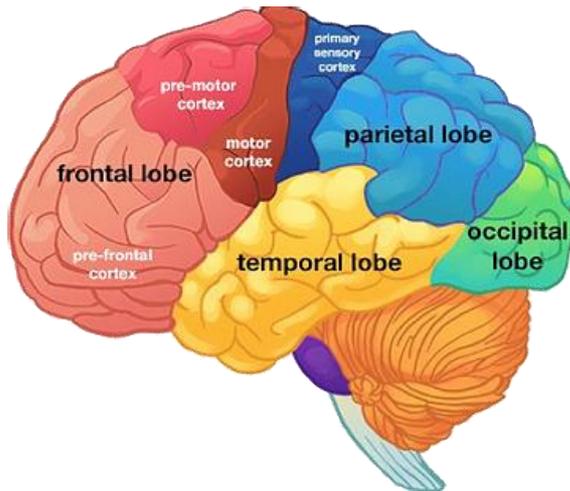


Figure 2: Functions of brain lobes (Cloverdale Rehab Clinic, 2020)

The front area of the **frontal lobe**, the so-called prefrontal cortex, executes complex action planning that shapes our personality. Other important areas of the frontal lobe are the Broca area, which controls our linguistic expressions, as well as the primary motor cortex, which sends movement impulses throughout the human body. Therefore, the primary motor cortex is jointly responsible for deliberate movement (Leyh 2011a).

The **parietal lobe** holds the primary somatosensory cortex, which processes information about the environment coming from receptor cells on the surface of the skin. Additionally, the parietal lobe holds information about the activity of tendons and muscles. This means, the parietal lobe is the place for the five senses, as well as self-perception. In the posterior parietal lobe of the parietal lobe proprioceptive, auditory and vestibular information are combined into a larger whole. Like this, a three-dimensional picture of our environment is created: this picture is permanently updated, which allows targeted movement and is also responsible for orientation (Leyh 2011c).

In the **temporal lobe** the auditory system, which transmits signals from the sensory cells in the cochlea of the ear, ends in the auditory cortex. This area is, among other things, the place for speech and music. The rear part of the temporal lobe, where it merges into the occipital lobe, mainly serves the visual center. Lexical centers in the temporal lobe reside where the auditory and visual centers overlap. They are responsible for the recognition of written and spoken language.

The temporal lobe also plays an important role in the memory. The entorhinal cortex, which is part of the temporal lobe, is the interface between things recently experienced and the memory system (Wicht, 2011).

In the **occipital lobe** the central processing of visual information takes place. It can be divided into the primary and secondary visual cortex, where the primary cortex creates the basis for processing the visual information. On the basis of this information, the secondary visual cortex develops more complex perceptions such as space, color, movement to the point of very specific objects (Leyh 2011b).

The **cerebral cortex** is the outer layer of the cerebral hemispheres. It is involved in receiving and processing sensory information, as well as thinking and other cognitive processes, planning and sending motor information. The **basal ganglia** is crucial to the function of the motor system. The **Diencephalon** lies beneath the two hemispheres of the Cerebrum. The Thalamus as part of the Diencephalon can be described as the door to consciousness, as it accommodates and transmits information coming from the sensory organs to the parietal lobe in the Cerebrum. It has to decide which information is passed-on and which one is sorted out. Beneath the Thalamus lies the Hypothalamus, which regulates survival specific internal behavior, as well as emotions and feelings. Also, it has control over the autonomic nervous system.

The **Mesencephalon** is the smallest part of the brain and is placed between the Diencephalon and the Pons. It is responsible for the sleep-wake rhythm and is associated with the motor functions of the human body. The **Pons** connect the Mesencephalon and the Medulla oblongata. In the Pons taste and especially hearing takes place, as well as it is responsible for autonomous functions, such as breathing. Together with the Pons, the Cerebellum forms the **Hindbrain**. The Cerebellum is responsible for coordination, in terms of balance, tonicity, memory involved body-related movement, as well as the coordination of arbitrary muscle activities. The **Extended Mark** is the transition from the brain to the spinal cord. Here many vitally important reflexes are located.

## **4. Neuroimaging Methods**

### **4.1. General remarks**

Neuroimaging helps to determine the presence of connection between cognitive processes and brain regions. Therefore, these methods are particularly useful in entrepreneurship research to investigate entrepreneurial behaviors and attitudes such as a desire for achievement, risk perception, control and lack of conformity. Indeed, it is assumed that entrepreneurs might have different expressions of character and personality traits compared to non-entrepreneurs, therefore neuroimaging tools would be able to capture such differences at the brain level (Massaro et al., 2020). The most common neuroimaging methods are the functional Magnetic Resonance Imaging (fMRI) and the Electroencephalography (EEG). While EEG measures “when” an activity occurs in the brain, the fMRI measures “where” (Bentzen, 2018). The fMRI method is very expensive, the machine costs can be carried out with more than US\$ 1 million and the experiments cost from US\$ 500 to US\$ 1000 per session (Massaro et al., 2020). This is one reason why the subsequent study of Prof. Dr. Eva Kirner and Prof. Dr. Markus Müller will conduct experiments via EEG. For the sake of completeness, more information about fMRI can be found in Appendix 2.

### **4.2. EEG**

EEG is considered a non-invasive technology, which captures and records the electrical activity of the human brain by using electrodes that are positioned on the subject’s scalp (Massaro et al. 2020). Thanks to the emergence of new technologies, brain waves can be measured more accurately and with less preparation ahead. Additionally, virtual reality technologies can be used in combination with the EEG to improve the quality of the final results, because participants are less distracted from the external influences (Dharmawan et al., 2021).

There are two different types of EEG, which depend on where the electrodes are placed: the first type is the EEG used on the scalp, where the major generators are extended patches of the grey matter. The second type is the intracranial EEG, also called iEEG (Michel, 2009). iEEG has been applied in most existing studies

related to epilepsy research and its main source is the synaptic activity in the brain. To carry out the iEEG, the researcher and the participant's brain should be in the same time and space continuum. Sufficient duration, strength and consistency are the most important aspects in order to have measurable and visible data about the cerebral electrical activity in the microvolt range. iEEG signals can reveal information about functional interactions within and between networks during different phases of neural computation. Most often, it is used to complement other neuroscience methods, to conduct research beyond replication of existing knowledge or on results that become known from non-invasive lines of research in humans (Parvitz & Kastner, 2019).

EEG functions by directly placing electrodes in elastic caps on the scalp to record the electrical activity of the brain cells. The EEG signal is generated by the so-called cerebral neurons and is obtained thanks to the electrically conductive properties of the tissue between the electrical source and the scalp, the conductive properties of the electrode itself, and the orientation of the cortical generator to the recording electrode. The process is also referred to as "volume conduction" because it relies on current flow through the tissue. This current flow occurs between the electrical generator and the recording electrode. The electrical charges are then digitally recorded and amplified. In the next step, the information can then be displayed as a continuous part of the so-called voltage values (Farnsworth, 2020).

In 2019, a Chinese study successfully attempted quantitative EEG-based predictions of individuals' Big Five Personality traits based on the former mentioned five-factor-model, which was shown in Figure 1. This involved assessing Big Five Personality traits using EEG recording. For example, extroverts have proven to be more likely to experience positive emotions, while people with high neuroticism scores are more likely to have negative emotions. Individuals whose brain activity is recorded via EEG signals will see a series of emotional words that are then fed as features into trained machine learning algorithms. The algorithms will then predict a value for each of the Big Five Personality traits using the signals that remain at a continuous level. However, for the traits agreeableness, conscientiousness, and openness, studies showed

inconsistent relationships between emotion reactivity and these personalities, but most studies suggest that these personalities influence people's emotional experience (Wenyu et al., 2019).

Because the EEG monitors the time course of electrical activity produced by the brain, it is possible to observe which areas of the cortex are responsible for or engaged in processing information at a given time. The temporal cortex is involved in processing sensory input into derived or higher meaning, which includes visual memories, language, and emotional associations. Medial regions are more involved with spatial navigation. Frontal cortex, in turn, is involved with executive functions. It helps us maintain control, plan for the future, and monitor our behavior. The EEG signal is always a mixture of several basic fundamental frequencies that are thought to reflect specific cognitive, affective, or attentional states. Each time your brain is in a particular state, the frequency patterns change and provide information about cognitive processes (Farnsworth, 2020).

The EEG is widely employed in entrepreneurial research, such in the case of the Flanker task. The Flanker task is a visual experience and during this task, participants must identify a specific target in two different experimental conditions. Then researchers can compare the entrepreneurial performance with the non-entrepreneurial performance as well as the brain waves of these two groups and should then be able to easily find out if there is indeed an alertness or readiness advantage for the first group (Day et al. 2017)

There are some limitations that are represented by the EEG, one limitation is that it is normally impossible to determine the EEG generators location only based on information recorded from the scalp. This problem occurs because the EEG converts a three-dimensional reality into a two-dimensional projection of that reality. However, EEG can bring considerable benefits to entrepreneurship research. First of all, it is less expensive when compared to other methods (such as fMRI). Second, the EEG results are less biased by unconsciousness. Finally, EEG experimental paradigms are easily reproduced and they are already validated in different social sciences studies. Based on the EEG, it could be made possible to identify different aspects in which entrepreneurs are better than others or to which entrepreneurs are more able. Subsequently, correlations between

trends or other variables should be detectable to be able to recognize that entrepreneurs are more able to identify a recurring pattern compared to people without entrepreneurial background (Olejniczak, 2006).

## **5. Entrepreneurial Characteristics and Cognitive Capacities**

Throughout the literature review of this study were identified at least fifteen different characteristics and traits thought to be fundamental for entrepreneurial behaviors. However, due to the time frame, only those traits perceived as particularly relevant for entrepreneurial activities, such as opportunity recognition and risk taking (Pott & Pott, 2015; Audretsch et al., 2016, Grégoire et al., 2010) are related to their operationalization possibilities via EEG. The following figure is also attached as Appendix 3, and it shows a summary of the correlations between the individual character traits and the responsible brain regions.

The mind map shows is divided into four big allocations of character traits. All of them are interrelated. Inside of each field of allocation there are various interrelations as well. All of them will be described in the following chapters in detail. The red boxes show to which places in the brain the respective character traits refer in literature. The big box connected to 'opportunity identification' shows a summary of the most important study, related to the operationalization via EEG, also described in detail in chapter 5.1 and 5.2.

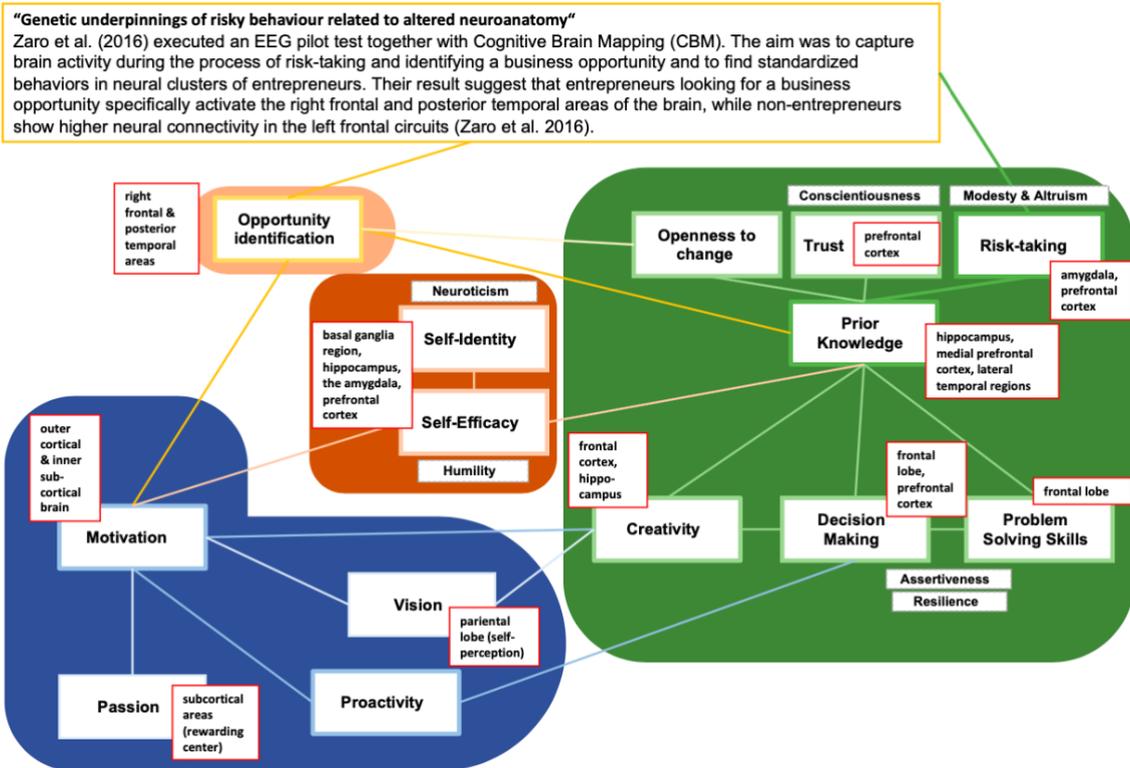


Figure 3: Characteristic traits of Entrepreneurs & Neuroimaging Methods

## 5.1. Opportunity Identification

One of the most important characteristics is opportunity recognition or, defined by Grégoire, Barr and Shepherd in 2010, the “efforts to make sense of signals of change to form beliefs regarding whether or not enacting a course of action to address this change”. Amongst other things, opportunity identification is a base for entrepreneurship and part of the most essential skills for success (Grégoire et al., 2010). Many studies have identified that the foundation of opportunity recognition relies strongly on the individual’s level of prior knowledge combined with a cognitive process of structural alignment acting as an analytical element. People with more prior knowledge tend to make decisions more automatically, more intuitively and more efficiently and therefore faster. Without this speed in decision-making, entrepreneurs might miss certain opportunities, as the time to act on opportunities is often limited. A number of studies also show that increased levels of prior knowledge in a particular area can lead to important advantages in the processes of risk-taking and problem-solving (Shepherd & Patzelt, 2018).

Prior knowledge is a part of the memory, which is located in the Hippocampus. The Hippocampus itself has extensive connections to the neocortical areas. The medial prefrontal cortex and lateral temporal regions in particular, are involved in retrieving the stored knowledge (Brod, et al. 2016). Focusing on the cognitive process, it comprises how the previous and new information will be processed and interpreted.

In the same study of 2010, Grégoire et al. found evidence for structural alignment theory when they analyzed participants' verbalization of the argumentation process for MIT's introduction of a new 3D printing technology. The authors identified two types of data alignment among participants. The first is a first-order structural alignment that relates superficial features of data, such as action verbs and their effects, or how a technology works and the benefits to an individual, as well as interest in it. The second type is a higher-order structural relationship that relates abstract information, such as causal chains or rules of condition, or underpins the benefits of a new technology. Thus, to identify an opportunity, it is necessary to draw on prior knowledge, but also to make a higher cognitive effort such as attention, which is suitable to encode such information at a deeper structural level (Grégoire et al., 2010).

Our brain stores countless pieces of information every day. The storage units for this information are found in the synapses, the fine branches through which the nerve cells in the brain interconnect. If certain information is now to be overwritten in the long-term memory, it means that the corresponding synapses must change permanently. In the cell nucleus, a mechanism is set in motion that releases certain proteins via the genes there. This process is called transcription (Delekate et al., 2011) and takes place also in the hippocampus, which is significantly involved in the storage of information in the brain, the synapses can be changed, both in the strength of the connection and in their own structure (Bonhoeffer, 2011). In principle, Grégoire, Barr and Shepherd found out that when entrepreneurs were presented with information about a new technology, they would consider the "similarities" between that, existing information and the context(s) in which this information could be useful (Grégoire et al., 2010).

As a behavioral and activity-based concept, tools and instruments have been developed to be able to measure entrepreneurial skills. One of these instruments developed by Kuckertz, Kollmann, Krell and Stöckmann, in their study of 2016, unites conceptual and methodological concerns in two scales that demonstrate reliability and construct to widely measure opportunity recognition and opportunity exploitation (Kuckertz et al., 2016).

A great reference for operationalization of this characteristic is study of 2016 which carried out an EEG pilot test, together with Cognitive Brain Mapping (CBM) to map the brain activity during the process of opportunity identification. The participants of the experiment were seven entrepreneurs and seven non-entrepreneurs. All entrepreneurs were classified as “established entrepreneurs”, meaning that they own and manage their consolidated business and pay salaries or other forms of compensation for more than 42 months (Zaro et al. 2016). The individuals were being placed in front of monitors, while they were connected to EEG electrodes (Zaro et al. 2016). According to the study, the entropy of the single electrode is calculated on a scale from 0 (red) to 1 (blue). If the area is blue, then it is possible to assume that the electrodes were activated, which implies that there was a significant cerebral activity. The CBM report the weight of information flow of each electrode and revealed three patterns of cortical neural connectivity. During the experiment, the individuals watched a video about opportunity identification in the jewelry market, afterwards they had to decide on loan options for investments in the jewelry market, which is referred to as taking risks (Zaro et al. 2016).

In this study, Zaro et al. (2016) pursued to find standard behaviors within neural clusters from entrepreneurs. It was operationalized with stimuli components like a video of a possible business opportunity followed by offering loan options to invest in such business shown to entrepreneurs and non-entrepreneurs. In Figure 4, brain map activities of non-entrepreneurs show their neural connectivity, colored in red, focused mainly on the left side. The first line shows a top view of the brain, the second line is the view of the left hemisphere and the third one shows the right hemisphere of the brain (Zaro et al. 2016).

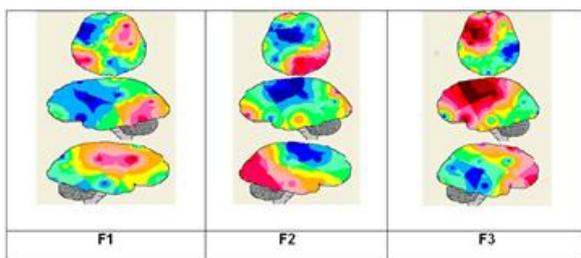


Figure 4: CBM of non-entrepreneurs during the search of opportunities (Zaro et al. 2016)

In the case of entrepreneurs, Figure 5 presents the results for some subjects and shows greater activation of neural connectivity in “frontal areas on the right hemisphere and posterior temporal areas”.

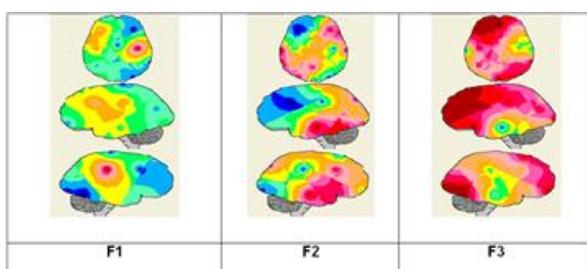


Figure 5: CBM of entrepreneurs during the search of opportunities (Zaro et al. 2016)

The presented pilot test will be also taken into consideration to operationalize risk taking behavior in the following section.

## 5.2. Risk-taking

As previously mentioned, innovation, exploration or entrepreneurship usually can involve great failure. Therefore, the three of them have been extremely related to risk-taking. Entrepreneurs are well aware of continuously changing market conditions, therefore they must be able to work with ambiguity. That is why they perceive more positively high-risk environments when compared to non-entrepreneurs. As a result, entrepreneurs' cognitive mechanisms make them more optimistic about a questionable activity or opportunity (Zaro et al. 2016). Generally speaking, some research show that the individual inclination to risky behaviors is influenced by the amygdala, the prefrontal cortex and the connection between the two (Berger, 2018). A larger amygdala is associated with taking

more risks. A stronger functional connection between amygdala and medial prefrontal cortex determines a greater tolerance for risks (Berger, 2018).

Furthermore, the study “Genetic underpinnings of risky behavior related to altered neuroanatomy” recognizes risk-taking as a behavior considered by some people as rewarded but involves exposure to negative consequences either social, financial or in health (Aydogan et al., 2021). This study used the voxel-based morphometry, a map that normalizes anatomical brain images built from MRI data, that allows to localize gray matter concentration (Ashburner & Friston, 1999), to identify which areas of the brain relate to such behaviors. They found an association in subcortical areas (thalamus, posterior, hippocampus, amygdala, putamen ventral striatum and cerebellum) and cortical areas (posterior middle temporal gyrus, precentral gyrus, anterior insula, dorsolateral prefrontal cortex and ventral medial prefrontal cortex). However, the study mentions the heritability of some brain features besides the environmental role of its development. In the hypothalamus, the release of hormones governs the functioning of the body's autonomic functions. While the hippocampus is mainly involved in the storage of memories, the dorsolateral prefrontal cortex has a major role in self-control and cognitive reasoning. The amygdala manages the emotional response to danger, while the ventral striatum is engaged in the processing of rewards. All these components are crucial when it comes to risk taking. In addition, prior knowledge is also playing a role in the assessment of risk and thus willingness to take risk (Aydogan et al., 2021).

The previous section has already explained the results obtained from the EEG measurement of opportunity identification. This paragraph will now consider the propensity to risk in decision-making among entrepreneurs and non-entrepreneurs. The following figures show cognitive brain maps probands with entrepreneurial and non-entrepreneurial backgrounds during the evaluation of propensity to risk.

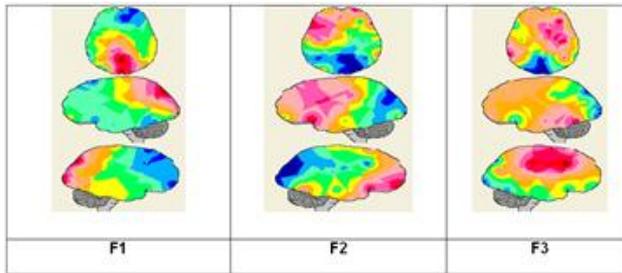


Figure 6: CBM of non-entrepreneurs during the process of risk-taking (Zaro et al. 2016)

Figure 6 shows the brain activity of non-entrepreneurs when making a decision about loan options.

Non-entrepreneurs revealed stronger frontal neural activity in the right hemisphere (see F1), bilateral posterior circuit (F2) and medial posterior circuit (F3) (Zaro et al. 2016).

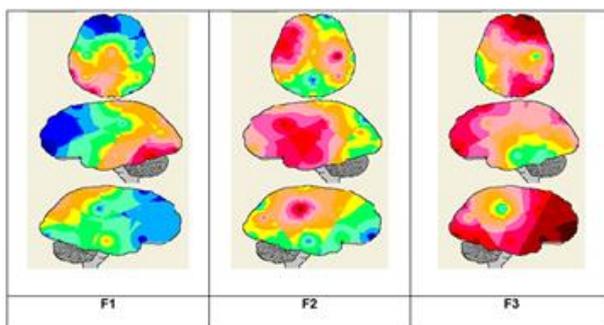


Figure 7: CBM of entrepreneurs during the process of risk-taking (Zaro et al. 2016)

On the other hand, Figure 7 shows that entrepreneurs employed a bilateral frontal circuit (F1) and another one including only a specific front area of the right hemisphere and another medial specific region in the parietal area (F2) while F3 does not show any brain stimulation. To conclude, it is possible to observe that the cognitive functions used by entrepreneurs were located in the left and right frontal regions of the brain. This is not a surprise, since, as said before, the frontal lobe is involved in strategic planning, decision making and multitasking. Furthermore, it also enhances the value of the missing opportunities. The study demonstrates that entrepreneurs collected first information about the business opportunities presented in the first step of the test and then they used that memory to assess the risk in each loan option. This assumption shows a higher level of engagement and commitment to the tasks demonstrated by

entrepreneurs, contrary to non-entrepreneurs. In fact, non-entrepreneurs would rely on a personal and limited framework in the case of risk-taking, while entrepreneurs have a broader perspective on different risk-taking possibilities (Zaro et al. 2016).

### **5.3. Proactivity**

According to the Cambridge dictionary proactivity is defined as “taking action by causing change and not only reacting to change when it happens” (Cambridge Dictionary, 2021e). Siebert and Kunz described proactivity in terms of cognitive skill as a learnable behavioral manifestation which is used during decision-making processes. In fact, proactivity is based on a systematic search for information, identification of objectives and alternatives in order to make a final decision. (Siebert & Kunz, 2016). Thus, it can be said that being proactive refers to the ability of recognizing and catching opportunities and problems forestalling (Olsen et al., 2018).

In everyday life, the human brain uses both a proactive and reactive system. The reactive system only switches on in unexpected situations, whereas the proactive system is constantly active. In the field of entrepreneurship, proactivity plays an important role. Being a proactive individual is crucial for opportunity identification and it helps entrepreneurs to act at the right times. A recent study shows that students with a higher proactivity level are more likely to start their own business. It is demonstrated that a proactive person has more chances to create a start-up in the future. Proactivity is something that can be learned or adapted at an intrinsic level. It is also closely related to other personality traits, such as opportunity identification, entrepreneurial intention, and self-efficacy (Cai Li et al. 2020).

Furthermore, proactivity is closely related to motivation (Siebert & Kunz, 2016). In fact, proactive entrepreneurs are usually intrinsically motivated, consequently they are more positive and it is easier for them to pursue their venture development despite all difficulties and obstacles they might encounter (Siebert & Kunz, 2016). Moreover, proactive entrepreneurs are more passionate about their ideas, so they tend to take higher risks in order to fulfill their objectives.

Higher level of proactivity implies openness to new experience, work centrality, self-reliance and entrepreneurial self-efficacy (Van Ness et al., 2020).

Concerning the brain location of proactivity, its level can depend on the white matter. Higher proactivity is associated with solid white matter connections between fixed brain regions. In addition, the level of fluid intelligence can also assess the degree of proactivity (Olsen et al., 2018). Fluid intelligence is the ability to think logically and solve problems and it can be found in the prefrontal cortex (Stangl, 2017).

However, proactivity is not directly measurable, therefore a multidimensional research instrument was created, called "Proactive Coping Inventory" (PCI). It was developed by Greenglass and Schwarzer. It measures proactivity according to the so-called proactive coping measures (Greenglass et al. 1999). The PCI consists of 18 subscales which describe various cognitive and behavioral dimensions. It is driven by proactive attitudes, which help to believe that improving your own world would also positively change the external environment (University of York, 2018). Such stronger beliefs are measured by higher PCI scores (Greenglass et al. 1999).

#### **5.4. Self-Efficacy**

Following Bandura's approach, perceptual self-efficiency is a powerful predictor of human behavior, which is also related to motivation (Bandura, 1997). Additional to that, there is to mention that self-efficacy is also critically important on how individuals respond to stress situations, especially psychological stress (Riopel, 2021). Self-efficacy is an influential component of education, social engagement, and medical treatment. However, studies that have examined the direct relationship between self-efficacy and neural correlates of consciousness have not identified specific brain regions, but they have assessed certain brain structures. Some studies hypothesized that the neural correlates of self-efficacy might be related to changes in the basal ganglia region (Nakagawa et al., 2017). The brain is a crucial element for responding to, coping with and recovering from stress. There is distributed neural circuitry within the brain that determines what is perceived as threatening and therefore stressful to an individual or in our case

the entrepreneur. The brain processes instrumental to this interconnection include the hippocampus, the amygdala and areas of the prefrontal cortex (McEwen & Gianaros, 2010).

Newer approaches connect self-efficacy directly to the field of innovation (Riopel, 2021). Self-efficacy can serve as an influential factor on aspiration and endurance on challenging work. Researcher showed that in an innovative setting, self-efficacy refers to an individual's belief in his or her ability to access necessary tasks for innovation. Additional to that, having a highly developed degree of self-efficacy helps individuals to accomplish and navigate successfully through complex environments (Gerber, et al. 2012).

### **5.5. Motivation**

Following risk-taking or in this case entrepreneurial behavior, one should understand the importance of rewards in the minds of entrepreneurs and where their personal motivation comes from (Shepherd & Patzelt, 2018). Motivation deals with the inner processes that give the general and entrepreneurial behavior of individuals their energy, direction and perseverance (Sounders, 2020).

According to Shepherd and Patzelt in the same study, the financial motivation for entrepreneurs can be taken for granted, but many are still driven by intrinsic or non-financial motivation. They also discuss that an individual's values, their psychological or physical health including their fear of uncertainty or the type of non-financial reward, can impact entrepreneurial motivation. Additionally they describe the positive relationship between the recognition of opportunities and the monetary reward (Shepherd & Patzelt, 2018).

For simplicity, the motivated brain and its many functions are usually divided into an outer cortical brain and an inner subcortical brain. Our basic drives and impulses, as well as emotion-rich motivations such as hunger, thirst, anger, anxiety, fear, pleasure, desire, reward, and wanting, are assigned to the subcortical brain. This includes the amygdala, basal ganglia, hypothalamus, and ventral striatum, the brain's reward center, as well as the ventral tegmental area, which is responsible for the production and release of dopamine. Thus, motivation is largely unconscious, automatic, and impulsive (Sounders, 2020).

In order to understand what type of motivation should be captured, it is necessary to effectively determine how to measure motivation. It is necessary to do so in order to consider different dimensions of motivation (Shepherd & Patzelt, 2018). Researchers typically measure motivation in form of observable responses. These may be cognitive responses, such as speed of recall or quality of perception. It is also possible to measure affective responses by analyzing self-reports of subjective experience and behavioral domains such as task performance. Brain activation can be used to evaluate physiological responses (Sounders, 2020).

However, motivation is strongly related to prior knowledge and creativity. Furthermore, motivation also relates to self-efficacy, as entrepreneurial profiles tend to be more interested in tasks they can “competently complete” and perform more efficiently (Sounders, 2020).

## **5.6. Vision**

According to the Cambridge Dictionary, vision is defined as “an idea or mental image of something” (Cambridge Dictionary, 2021h). In the entrepreneurial context, it might be related to the ability to imagine how a business idea could look developed and established on the market. Vision is considered the driver of entrepreneurs, because it gives them a reason to dare, to try even after drawbacks and, in the best scenario, to succeed (De la Torre, 2016). In other words, vision gives them a goal to reach. Therefore, for the start-up founder, it is essential not only to have an innovative and creative idea, but also to have the energy to pursue that idea.

Vision establishes the cultural framework of the start-up because it includes all the values and principles that the entrepreneur believes in and that are then spread to the whole organization. Vision is strictly related to other personality traits of start-up founders mentioned here, such as creativity, motivation and passion (De la Torre, 2016). The concept of vision is also connected to self-identity, which is defined as the belief “that you are a particular kind of person, especially when other people do not think that you are that kind of person”

(Cambridge Dictionary, 2021g). Self-awareness is located in the parietal lobe of the brain, where the five senses are also located (Guy-Evans, 2021).

Creative thinking is one approach to develop the vision. It consists of four steps: preparation, incubation, illumination and verification. Preparation includes planning and information collection, incubation requires that the unconscious mind continues to think about the task or idea, while the conscious mind is focusing on something completely different. During the incubation, the individual will have a sudden inspiration, which is the illumination step. Finally, the inspiration is made conscious, therefore it is possible to test and implement the vision statement as a verification (Lavery & Little, 2020).

### **5.7. Passion**

Passion is a very important characteristic among start-up founders. It stimulates creative thinking, drives motivation and helps to develop the vision. Literature defines two main components of passion: positive feelings and identity centrality, which refers to the importance of the task to the identity of the person (Lex et al., 2020). Current research analyses passion in the entrepreneurial context, where passion is defined as “consciously accessible intense positive feelings experienced by engagement in entrepreneurial activities associated with roles that are meaningful and salient to the self-identity of the entrepreneur” (Newman et al., 2021).

Passion is connected to the rewarding centers of the brain, there are placed within the subcortical areas (Berridge & Kringelbach, 2015).. Additionally, self-identity is important among entrepreneurs since it allows the identification and development of true passions. It is more likely that the idea will be carried out because it perfectly fits with the identity of the entrepreneur. Moreover, strong positive feelings, such as enthusiasm, have a positive impact on opportunity identification, which implies that start-up founders are more likely to recognize new opportunities compared to other individuals (Feng & Chen, 2020).

## 5.8. Creativity

Creativity is considered a multidimensional entity connected to both cognition and emotion: two key mental processes that mutually interact and form psychological phenomena. It is relevant in the start-up context because creativity can be interpreted as the “exploitation” of multiple intelligences which aims at generating new ideas (Simeng et al., 2018). In fact, start-ups are based on the creation and development of innovative and creative products or services (Sawyer et al., 2003). Research has recognized the significance of creativity for the creation and survival of firms in highly complex and competitive environments, such as in our case an entrepreneurial context (Parjanen, 2012).

Due to its complexity, it is not possible to locate creativity in a single brain region (Cavdarbasha & Kurczek, 2017). Some studies demonstrate that creativity is associated with the frontal cortex, because the brain area is responsible for many functions which imply creative thinking, such as for example working memory. Recent research also takes into consideration the hippocampus, which is the storage of facts or past experiences. Thus, the hippocampus can trigger creative thinking by connecting all the stored information in a new and original way, allowing the generation of new ideas (Cavdarbasha & Kurczek, 2017). Studies related to creativity have discovered that individuals can be driven to entrepreneurial behavior by intrinsic motivators. Prior knowledge therefore positively stimulates creativity (Shepherd & Patzelt, 2018).

Creativity can be measured using the creativity quotient (CQ), psychometrics, and the social personality approach. In contrast to traditional IQ, some tests take imagination into account. In psychometrics, questionnaires are used to assess abilities, character traits, educational achievements, and knowledge in creative areas, such as art, writing, humor, inventions and more. Finally, the social personality approach measures other personality factors associated with creativity, such as risk-taking and conscientiousness, and can therefore determine the level of creative thinking (Kaplunov, 2020).

## 5.9. Problem-Solving & Decision-Making

Problem solving and decision making are personality traits that are critical for start-up founders. In the high level of uncertainty and the rapidly changing environment they have to cope with, there are usually many challenges they have to solve. And since they don't want to lag behind their competitors, they have to decide very quickly while still critically evaluating them. In addition, creativity is required in problem solving and decision making in order to find creative solutions. Prior knowledge is also very important to solve problems, as entrepreneurs should have personality traits such as 'Business and Industry Knowledge', 'Evaluate Details' or 'Critical Thinking', as Figure 8 shows (Shepherd, 2018; Lavery, 2020).



Figure 8: Skills connected to problem-solving (Open Education Resource, 2020)

Figure 8 illustrates some of the skills that entrepreneurs acquire that help in problem solving. Problem solving is situated in the frontal lobe of the brain and is connected to sensory and memory centers scattered across the brain, meaning that when problems need to be solved, one draws on information stored in another location (UPMC, 2014). Also included in problem solving behavior is the anterior cingulate cortex, which connects the limbic system, responsible for emotions and the prefrontal cortex, responsible for cognitive behavior. This leads to the conclusion that both cognitive and emotional demands are taken into

account when it comes to solving problems (Swaminathan, 2008; Stevens, et al., 2011).

To make decisions, the brain also uses the frontal lobe, more precisely the ventrolateral prefrontal cortex and orbitofrontal cortex, which are highly interconnected. The Ventrolateral prefrontal cortex was detected to be involved in tracking reward probability, choosing according to outcome probability, probabilistic learning and contingent and noncontingent learning. Meanwhile, the orbitofrontal cortex is involved in the ability to choose according to outcome value. This means that the ventrolateral cortex is responsible for making decisions based on the probability of the outcome and the reward and learns from previous decisions, while the orbitofrontal cortex makes the decisions based on the value of the outcome (Rudebeck, 2017).

To measure problem solving skills and decision making often some kind of games are used, to test these skills in a specific context. (McDonald, 2017; Finucane & Gullion, 2010; Shute et al., 2016).

### **5.10. Resilience**

Entrepreneurial Resilience is often investigated in the context of a failure or a paralyzing experience (Corner et al., 2017). In normal use of language, resilience is defined by “the ability to be happy, successful [...] again after something difficult or bad has happened” (Cambridge Dictionary, 2021f). Resilience has gained increasing importance in the sphere of entrepreneurship (Corner et al., 2017). The overarching topic of resilience can be subdivided into several dimensions such as organizational actions for external challenges, reliability of organizational issues, employee strength, general ability to adapt to different circumstances or business models and design principles of the organization (Linnenluecke, 2017). Most entrepreneurs show a certain kind of resilience, because they demonstrate stable levels of functioning. This kind of stability has to be differentiated to what psychologists designate as ‘recovery’. There is a lot of available literature when it comes to the relationship between the different resilience dimensions and entrepreneurial intentions and self-efficacy (Corner et al., 2017). One of the most famous measures when it comes to resilience is the Connor-Davidson Resilience

Scale. With an extensive number of studies using this tool, conducted within a varied range of populations, the CD-RISC is considered one of the higher scoring scales in the psychometric evaluation of resilience. It is a validated and widely accepted scale that measures resilience as a function of five interrelated components: Personal Competence, Acceptance of Change and Secure Relationships, Confidence, Tolerance, Strengthening the Impact of Stress, Control, Spiritual Influences (Ackermann, 2021). Generally speaking, it can be said that resilience is often approached very differently in the literature and the way it has been conceptualized also varies a lot (Linnenluecke, 2017).

### **5.11. Assertiveness**

Assertiveness is “the quality of being confident and not frightened to say what you want or believe” (Cambridge Dictionary, 2021a) and it is a crucial entrepreneurial trait, as an Entrepreneur needs to self-actualize his vision. A high level of assertiveness not only leads to better self-actualization, but also to lower anxiety levels and a need for achievement, of which an entrepreneur can benefit from (Dilgasa, 2018). Assertiveness is also considered as one narrow personality trait under the Big Five Personality traits. Research by Çelik et al., show that at least one of the narrow personality traits under the Big Five Personality traits has a significant impact on the entrepreneurial intention of undergraduate students (Çelik et al., 2021).

The “Rathus Assertiveness Schedule” (RAS) was designed by Rathus to measure the level of assertiveness a person has. It is a self-reported test, where high positive scores indicate a person’s high level of assertiveness, while a high negative score indicates the opposite (Rathus, 1973; Caballo & Salazar, 2017).

### **5.12. Conscientiousness & Trust**

Conscientiousness is usually conceptualized as a personality trait that mirrors the tendency to be self-disciplined, goal-oriented, self-controlled, responsible to others, hardworking, orderly and compliant with rules. Higher levels of conscientiousness dependably predict a range of preferable life outcomes, including both longevity and better health across the lifespan. Additional to that

there is an existing positive relationship between conscientiousness and desirable behaviors and outcomes (Javaras et al., 2017). Different instruments can be used to operationalize conscientiousness. OPERAS is one of the popular ones, that captures the Big Five Personality traits through seven items per one dimension with a Likert response ranging from one (strongly disagree) to five (strongly agree) (Postigo et al., 2021).

Trust is a personality trait that everyone needs, whether it is in their personal lives, when it comes to relationships, or in their professional lives. For entrepreneurs and start-up founders, trust is essential because they need to believe and rely on themselves as well as on others to fulfill their vision. Trust is located in the medial prefrontal cortex, which is also important when it comes to making decisions, as well as being the place of foreknowledge (Bergland, 2015). This refers to the decision to trust someone or something that we make based on our prior knowledge. And we use trust to make decisions. Especially in uncertain and risky times, we need to have trust in ourselves and others, which is especially important for entrepreneurs who have to deal with a lot of uncertainty and risk (Bauer & Freitag, 2018; Vanhala, et al. 2011; Glaeser, et al. 2000; Evans, 2016).

### **5.13. Openness to change**

Openness is defined as the “willingness to accept new ideas or changes” (Cambridge Dictionary, 2021d). As already mentioned, openness is one of the Big Five Personality traits, along with conscientiousness, extraversion, agreeableness and neuroticism (Cherry, 2020).

Individuals characterized by high openness tend to embrace original ideas and they pursue novelty even if it is riskier than just following the trend (Cherry, 2020). They usually engage in creative activities, they are imaginative and curious. Furthermore, openness is strictly related to intrinsic motivation, since individuals embrace knowledge for its own sake. It is evident why entrepreneurs show a high level of openness, considering that start-ups are fully based on innovative and disruptive ideas.

Without openness, people would not be able to identify opportunities and then transform it into a competitive advantage. Several researchers found that

openness is a good quality for entrepreneurs because it helps the individuals to adapt to new technologies, competitive and changing environments and it facilitates the creation of innovative solutions (Slavec et al., 2017).

#### **5.14. Neuroticism**

Neuroticism is another important cognitive capacity in the field of start-up founders and entrepreneurs. This personality trait is one of the elements of the five-factor-model, which is described in Figure 1. Neuroticism is described as the tendency to have unsettling feelings and thoughts. A low degree of neuroticism leads to higher confidence, higher resilience and more relaxed behavior in stressful situations. In contrast, a high neuroticism score implies a high level of frustration and blaming oneself for mistakes more easily and often (Chrystal, 2019). Neuroticism is an important characteristic for entrepreneurs. For being a successful entrepreneur it is crucial that the neuroticism level is relatively low and the level of emotional stability is high as a high neuroticism level is likely to decrease the ability and also propensity to take risks (Rym et al. 2018). So it can be stated that a higher degree of neuroticism can be considered as the opposite of emotional stability because it involves feelings belonging to negative emotionality, such as anxiety, nervousness, sadness and tension (Chrystal, 2019).

Neuroticism can be located in the amygdala and the cingulate cortex because they are responsible for negative emotions. Thus, a bigger development of these two areas imply a higher level of neuroticism (Tomoyo et al. 2016).

#### **5.15. Altruism & Modesty**

Altruistic individuals are willing to do things for others even though they don't receive any personal advantages (Cambridge Dictionary, 2021b). Altruistic behavior is voluntary-based, so it does not include situations when a person is just obliged to help others (Rodrigues & Hewig, 2021). When looking at the big 5 personality trait model altruism belongs to agreeableness and so it can be said that the level of altruism is relatively low regarding the personality of entrepreneurs (Saroj, 2021). The Hexaco-Model was created to better

differentiate the different nuances of altruism (Rodrigues & Hewig, 2021). The model aims at showing altruistic behavior in a practical experiment called the Dictator Game. The game is structured the following way: there are two existing roles that can be chosen, the receiver and the allocator. The allocator receives a certain amount of endowment and is allowed to distribute it to himself or make a one-time offer to the receiver, who is not able to refuse the offer, to give him a certain amount of the endowment. It is assumed that allocators keep all the money for themselves, but the experiment has shown that a significant minority act altruistically and give part of the money to the receiver (Bekkers, 2007).

A modest person is not trying to make people notice his or her achievements and abilities. The sources of modesty are motivational and cognitive, therefore it requires the understanding of the second order mental states that are involved in the process. Second-order theory of mind, also called second order mental states, are involved in forecasting what one person thinks or feels regarding what another person thinks or feels. It is not only important to understand the above mentioned mental states but also additional motivational concerns should be considered by entrepreneurs (Shepherd & Patzelt, 2018).

## **6. Conclusion**

Start-ups are a very important factor for economic growth. Furthermore they provide independence for employees. Entrepreneurial thinking gets a higher priority in the future world of work, therefore, it seems logical that researchers are trying to find out how to enhance entrepreneurial thinking.

Neuro-entrepreneurship is gaining in importance, although it is still a very under-researched field. Especially, the operationalization of personality traits and characteristics with respect to entrepreneurial activities is a research field which should be exploited more in the future. There are a lot of different neuroimaging methods which can be used for further research. The fMRI, although it is more accurate, is used not as often as the EEG due to practicability as well as for cost reasons.

To answer the previously developed research question: "Which neuro-psychological characteristics and parts of the brain are responsible for

entrepreneurial activities in the brain?”, it can be said that the Cerebrum seems to be the most important part of the brain to pursue entrepreneurial intentions as it processes impressions from the environment and decides if and how to react upon these impressions. Entrepreneurs react to environmental circumstances and see as well as create needs that did not exist before, wherefore the interaction with the external environment is one of the most important factors for entrepreneurial activity. Especially the frontal lobe, as part of the Cerebrum, is very important, as many previously discussed characteristics like self-efficacy, prior knowledge, risk-taking, trust, problem-solving, decision-making are located in the frontal lobe. Additionally, most of the discussed characteristics seem to be important in the pursuance of entrepreneurial intentions. A lot of them have connections to the frontal lobe, leading to the conclusion that a well-trained frontal lobe is crucial for entrepreneurial activities. Therefore, it is necessary to know how to properly train and activate the frontal lobe.

Nevertheless, there are also some other parts that need to be considered, like the parietal lobe or the temporal lobe. Also, the diencephalon is essential, as it influences which information is passed on and therefore gets to be processed. This is relevant as one can only pursue entrepreneurial intentions based on what the person has information upon.

Nonetheless, it has to be recognized that the mentioned characteristics are not equally important. Some of the characteristics, like risk-taking, opportunity identification and proactivity, seem to have higher importance if one wants to become a successful entrepreneur.

However, it is very important to recognize that, although there are some traits entrepreneurs benefit from when it comes to their entrepreneurial activity, it is not yet proven that specific character traits that are more distinct compared to non-entrepreneurs, automatically make an entrepreneur. Each individual is different, there are just certain characteristics and personality traits that entrepreneurs are more likely to have because if these special traits are more developed in a personality one is more likely to become a successful entrepreneur than another person (Obschonka et al., 2019; Sting, 2019; Tuğba, 2016). Also, not only internal factors and neuropsychological characteristics are important for entrepreneurial

activities. The interaction between internal and external factors are crucial when entrepreneurial intentions want to be pursued, especially as the human brain and its development is influenced by external circumstances. Additional to that, it is elementary that the entrepreneur not only has certain characteristics and personality traits, but is also able to put the theoretical science on an integrated management concept, as other knowledge can contribute to it.

## **7. Limitations**

Working on a secondary literature project it has to be mentioned that primary data that has been collected by yourself is gathered for a particular purpose: to address a research question and to achieve your objectives. Other than secondary data, which has been collected for a specific purpose that is different from your research question or objectives. Consequently, the data considered may not be as appropriate for the present research question as primary data would be. Another limitation is also that the data was collected a few years earlier and is therefore not completely up to date. In addition to this, the collection methods of the original data sources that were later merged into our intended secondary dataset are different. In order to work as precisely as possible, sources not older than about five years were chosen for all secondary data that contributed significantly to the research result. Of course, the present work also includes sources that are much older. However, these have not contributed significantly to the result of the work, but have been included to complete the basics. The number of current and thus non-peer-reviewed publications in the field of neuroscience and personality trait related research, is gradually increasing. In order to expand this field of research and include all necessary components, it was essential to include non-peer-reviewed articles and publications.

As data has been used and presented as part of a report, it is also necessary to be aware of the purpose of that report and the implications, as this has influenced in a certain way how the data is presented. This is especially true for internal organizational and external documents such as published company reports and newspaper stories (Saunders, Lewis, & Thornhill, 2019).

Overall, it is difficult to make meaningful statements about which traits influence startup founders, and to what extent the expression of the traits is related to personality or the content of the work.

There is evidence in the literature about the influences and role of gender in entrepreneurship, which the present paper has not further examined. For women, the desire for independence predicted the intention to become start-up founders. Women expressed lower entrepreneurial tendencies when job security was important to them. In contrast, for men, the need for achievement and risk taking had a significant influence on entrepreneurial intention. Women were found to have lower levels of risk taking compared to men. However, there were no significant differences in the type of entrepreneurial intention (Yukongdi, 2017). Additionally, differences in neuroscience approaches were not considered further in the present work. For example, there are approaches that show there are differences between the gray matter of the brain and gene expression of the different genders (Liu et al. 2020).

## **8. Outlook**

Clearly, further research is needed. The findings of this paper can be used for further theoretical and practical research. Researchers should use it as a base to proceed into deeper entrepreneurial research about brain activities and possible operationalization methods of entrepreneurial characteristics. Additionally, further research is needed to conduct further research about which characteristics differentiate entrepreneurs from non-entrepreneurs, and how significant the impact is. As already mentioned before, secondary literature review is usually followed by a qualitative or quantitative analysis (Snyder, 2019), which will in this case, be carried out by Prof. Dr. Eva Kirner and Prof. Dr. Kai-Markus Müller. The focus of this subsequent project will be to measure brain waves of entrepreneurial active people and compare them to see whether one can find a neurological proof if there is a significant difference.

„It's not about ideas. It's about making ideas happen.“

– Scott Branson

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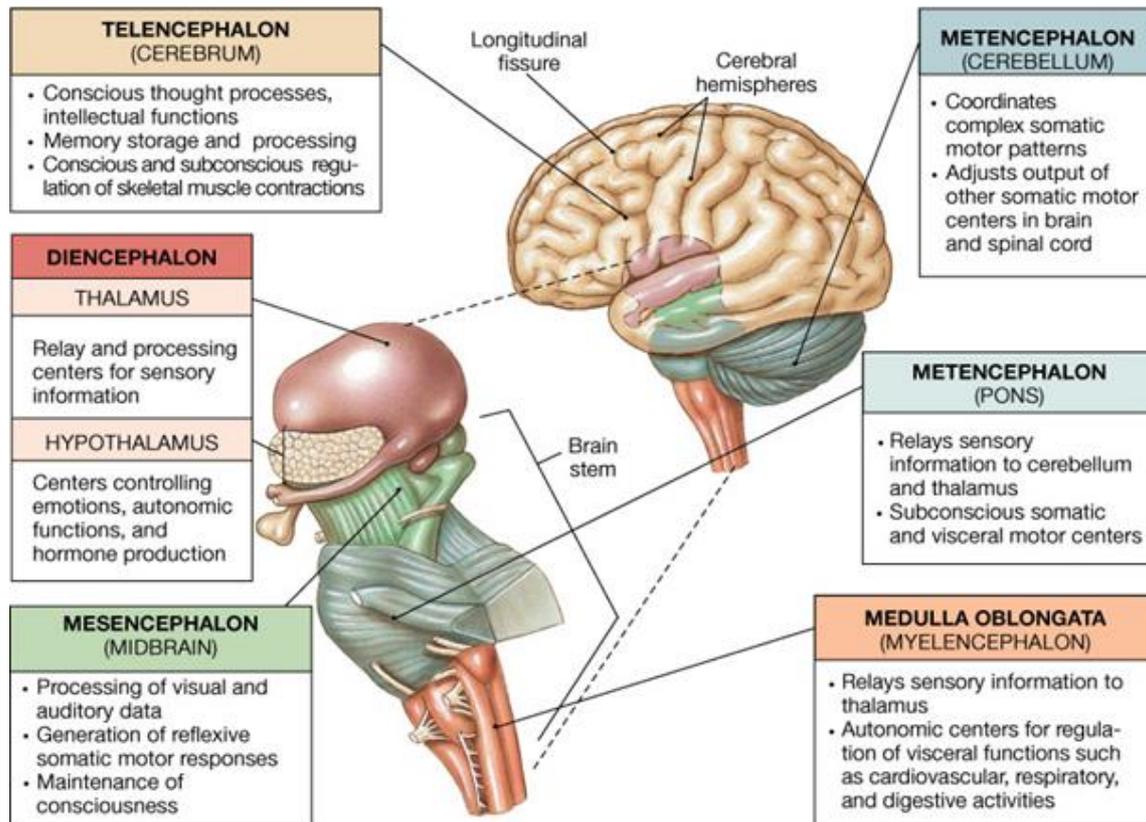
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## Appendix 1 - The human brain



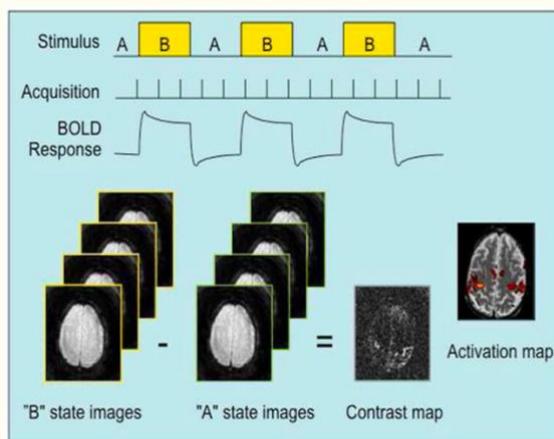
Source: Droual (n.d.)

## **Appendix 2 - Relevant Information about fMRI**

The fMRI measures brain activity by capturing changes associated with blood flow in the brain” (Massaro et al., 2020). More in detail, the blood tends to flow in the specific brain area, also called the “activated brain region” in this context. This area is actively engaged in a task or activity in order to release essential nutrients and oxygen. The level of oxygenated blood is more concentrated in the activated brain region and it is associated with the BOLD (Blood-Oxygenation Level Dependent) signal. The fMRI is able to perceive the variation of this signal in a fMRI measurement, the individual rests or performs an activity which consists of a magnet generating a strong magnetic field that is applied constantly across the brain (Massaro et al., 2020). The fMRI technique is very common in entrepreneurial research for its several advantages. In fact, its good resolution allows detailed imaging, it creates dynamic maps of moment-to-moment brain activity which is useful when the individual engages in tasks (Massaro et al., 2020). The technique is being used to study several cognitive functions associated with brain sites: in fact, it perceives fear and alarming stimuli which activate the amygdala, it captures reward processing and anticipation and it provides some insights into rational decision-making which triggers the prefrontal cortex, and into pain, which activates the insula (Massaro et al., 2020). All these cognitive functions are useful in the entrepreneurial research for several reasons: they give some information about the role of fear and fear of failure across different start-up founders, they deepen the knowledge on opportunity evaluation, they stimulate the understanding of pervasiveness and optimism in entrepreneurs, they differentiate entrepreneur from non-entrepreneurial thinking. In addition, the other cognitive functions highlight the rationality of start-up founders’ decision-making processes and finally they analyze differences in resilience and grit (Massaro et al., 2020).

A typical fMRI task activation experiment uses visual, auditory, or other stimuli to alternately induce two or more different cognitive states in different subjects. In a two-condition design, one condition (which in the entrepreneurial context could also represent a feeling or emotion associated with the trait) is referred to as the experimental condition, while the other is referred to as the control condition. The

goal is to test the hypothesis that signals differ between the two conditions. Here, for example, one might test two control groups. A control group with entrepreneurial background and a control group with a non-entrepreneurial background. fMRI experiments in block design, as shown in the following figure, show a neural response to the change of condition from A to B. The neuronal response to the change of condition from A to B is shown in the following figure (Glover, 2012). Rapid and continuous acquisition of MR images sensitive to BOLD signal changes are acquired. Using single- or multivariate time-series analysis methods, the average signal difference between the two states for the scan is calculated and a contrast map is generated as shown in the following illustration by Glover (2012).



Source: Glover (2012)

However, fMRI also has considerable limitations. It shows some delays when a reaction occurs due to its low temporal precision, it may cause discomfort because it requires participants to lie in the machine for a long time (60-90 minutes) and it makes a lot of noise (Bentzen, 2018). Additionally it has a remarkable physical presence, plus it is expensive: the machine costs more than US\$ 1 million and the experiments cost from US\$ 500 to US\$ 1000 per session (Massaro et al., 2020).

Therefore, it is evident the relevance of fMRI in the entrepreneurial context: it allows the identification of some attitudes or behaviors which might be recurrent in start-up founders and differ from non-entrepreneurs. However, its application has some disadvantages as well and researchers might prefer to use more other effective tools.

## Appendix 3 - Characteristic traits of Entrepreneurs & Neuroimaging Methods

