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WHO AM I?

The Neurobiology of Big Five

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Abstract

Personality is something that sets every human being apart, yet it is something that has been quite hard to pinpoint. Recently, neuroscientists have begun pinning down the neural correlates of personality traits – with focus on the Big Five, sparking a whole new subfield within personality research, known as personality neuroscience. By using neuroscientific methods and techniques to find the underpinnings of the Big Five have led to a deeper and broader understanding of how genetics and the environment integrate into making individuals who they are. This research has also been helpful in the prediction of various outcomes e.g. academic performance and achievement and neuropsychological disorders. In this thesis, the supposed neural correlates of the Big Five are examined through thorough and critical investigations, where evidence from some of the existing relevant studies is reviewed and compared, as well as the different problems and complexities that the field of personality neuroscience is dealing with. The findings in this thesis shows that extraversion has neurobiological basis in the frontal areas of the brain, neuroticism with reduced volume in the frontal areas, agreeableness with frontoparietal areas that are related to theory of mind as well as temporal regions, conscientiousness with frontal parts that are associated with planning and goal-orientation, and openness/intellect with frontoparietal areas as well as subcortical regions, which have been linked with intelligence and creativity. However, some of the correlations were inconsistent and scattered and further research needs to be done. The analysis of academic achievement and performance, as well as neuropsychological disorders and the Big Five with neuroimaging as a method, have shown to be limited, thus much more research is needed.

Keywords: personality, Big Five, neurobiology, outcomes

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Introduction

Personality is something that we all have in common and yet it is something that set us all apart. We all differ in how we behave, why we think the way that we do and certain interests that we have. We already know that our personality traits may not match up with others, what we do not know is - why are we different from each other? What makes our emotional reactions to being distinct from others? How come my motivations differ from those of my peers? There seems to be a lack of consensus on the neuroscientific foundations to these questions.

Some would say that personality is caused by our adaptation and are purely based on nurture and environmental factors with the implication that humans are essentially “blank slates” which has been advocated for by prior psychologists and philosophers such as Locke, Pavlov, and Watson. While others would say that personality is already biologically determined by our genes and are even hereditable (Ham et al., 2004; Polderman et al., 2015). As a matter, in fact, it has been proposed that roughly 49% of personality traits are heritable (Polderman et al., 2015). Temperamental personality traits are something that has been shown to be determined by genes and are unchangeable throughout life (Balestri, Calati, Serretti, & De Ronchi, 2014). Then there is the field of personality psychology which according to McAdams & Pals (2006) describe personality as "an individual's unique variation on the general evolutionary design for human nature, expressed as a developing pattern of dispositional traits, characteristics adaptions, and integrative life stories complexly and differentially situated in culture" (p. 9).

As a result of the research from personality psychology alongside with the recent development of human neuroscience, the field of personality neuroscience has emerged. According to personality neuroscience, personality is suggested to be a mixture of genes, environment, brain structures, and neurochemistry (DeYoung, 2010).

Personality is compounded of several dimensions; traits, characteristic adaptations, and life stories (DeYoung, 2010). Personality neuroscience has its focal point on the traits of personality since traits have been shown have a high rate of heritability (Bouchard, 1994; DeYoung, 2010; Ham et al., 2004) and are stable patterns cognitive functions and behavior (DeYoung, 2010; DeYoung & Gray, 2009). Personality traits have suggested being able to predict different outcomes such as jobs, academic achievement and performance, relationships, and neuropsychological disorders (Bogg & Roberts, 2004; Poropat, 2009; Roberts, Lejuez, Krueger, Richards, & Hill, 2014; Wright et al., 2006; Wright, Feczko, Dickerson, & Williams, 2007). It has been shown that damages or deficits on brain areas can lead to personality changes (Gazzaniga, Heatherton, & Halpern, 2016), which indicates that brain structures play an important role in the matter of personality. This would indicate that studying not only healthy subjects but also subjects with neurological disorders or brain deficits that cause personality changes, can tell one thing or another about personality itself. Personality has been indicated to be a prominent factor in the vulnerability of depression (Takano et al., 2007). Moreover, it has been implied numerous times that the personality trait *neuroticism* has been considered a predictor of mood disorders (Wright et al., 2006; Wright et al., 2007), which further incites the curiosity to look into the relationship between personality traits and the proneness for the vulnerability of neuropsychological disorders. As for academic achievement and performance, the research in this field has been confounded with the question of what could be the contributing predictor for it. For what it seems like, cognitive ability – IQ and intelligence – have been one of the key predictors for academic achievement and performance (O’Connor & Paunonen, 2007). However, recently it has appeared that cognitive ability alone cannot predict individuals’ accomplishment in the educational world (O’Connor & Paunonen, 2007). Personality dispositions seem to have a major role in the prediction of academic success (Chamorro-Premuzic & Furnham, 2003a; O’Connor & Paunonen, 2007). As a matter of fact, cognitive ability has been implied to have lost its predictive powers at a higher level of education (O'Connor & Paunonen, 2007). This problematization has led to a broader interest in the relation between personality traits together with its neurobiology, and academic achievement and performance. The recent interest has prompted a deeper investigation into which personality traits could be the predictor of academic success and what would be the underlying reason behind it and the neurobiological basis responsible for it.

Nevertheless, in order to measure personality, one must have models and methods that are adequate and suitable.

The Big Five

The Big Five (can also be called Five Factor Model or FFM) - is a well-known and shown to be a suitable model to measure personality traits and its corresponding neurobiological basis (Costa & McCrae, 1992; DeYoung, 2010; DeYoung & Gray, 2009; McCrae & John, 1992). Big five consists of five factors which reflects numerous diverse traits have been summarized into - O*penness to experience, Conscientiousness, Extraversion, Agreeableness, and Neuroticism* (Costa & McCrae, 1992). Each factor reflects a wide collection of behaviors (Bjørnebekk et al., 2013) and can without difficulty be operationalized with questionaries (DeYoung & Gray, 2009). Openness to experience (can also be referred to as Intellect) can be interpreted as a tendency to seek out novelty and variety and manifested as intellectual curiosity and interests (Briley, Domiteaux, & Tucker-Drob, 2014). Conscientious people can be characterized as organized, disciplined, and achievement-oriented (Johnson, 2014). People with high scores on extraversion are sociable, talkative, warm, cheerful, gregarious, assertive, and like excitement and activity (Kajonius & Johnson, 2018). Agreeableness displays as helpfulness, sympathy, and cooperation (Goldberg, 1990). Neuroticism demonstrates aspects of emotional negativity, stability, anxiety, vulnerability, and impulse control (Bjørnebekk et al., 2013). These factors of traits have been shown to be stable over time, heritable, having a correlation with neurobiological bases, and are universal (Costa & McCrae, 1992). The Big Five could be a prediction for different matters such as; personality disorders, academic performance, job choices, and relationships outcomes (Bogg & Roberts, 2004; Poropat, 2009; Roberts et al., 2014; Wright et al., 2006; Wright et al., 2007). Studies have shown that the neurobiological basis of the Big Five factors such as; *extraversion* and *neuroticism* may contribute to mood- and anxiety disorders (Wright et al., 2006; Wright et al., 2007). In addition, Big five can together with development research contribute to further understanding of the development of personality throughout an individual lifespan (Allen & DeYoung, 2017). Therefore, it will be an appropriate model to use for analysis of the neurobiological basis of personality and the predictions that come with it. Although it is the most suitable model to use, there is some inconsistency in the field regarding the factors of the Big Five. Some have stated that certain factors of the Big Five have traits and facets that are so similar that the factor might as well be blended together.

Present Study Aims and Structure

The main aim of this thesis is to describe the neurobiology underlying personality traits. In order to achieve this aim, the underpinnings of each of the Big five factors will be examined. The overall goal of this literature review is to contribute with research for a broader understanding of the personality traits or the factors of the Big Five. As mentioned above, the exploration of Big Five has led to further investigations of the correlations and predictions of certain domains which have been a contributor to various research in the neuroscientific field. Therefore, a brain mapping of the Big Five would give a deeper picture of how personality traits work and perhaps predict the probability of the vulnerability of neurological disorders based on either the heritability of a personality trait or the likeliness of the correlation between a certain trait and its relationship to neurological disorders, or both (Cremers et al., 2011). There seem to exist numerous studies showing that there could be a correlation between the factors of extraversion and neuroticism and mood disorders such as depression and anxiety, which will be discussed later in the thesis. Furthermore, it could lead to a possibility to provide templates for individualized treatment and medication in the future. It could also show the link between the Big Five and academic performance which is relevant because it would provide further knowledge into the understanding of the underlying factors contributing to the ability to thrive in education and learning. This understanding could potentially open up for the opportunity to unfold curricula that could improve the levels of academic performance for most (O'Connor & Paunonen, 2007). In addition, it could provide further comprehension into which personality traits could be predictors of academic success.

The structure of this thesis would be to firstly, present and give a background into the preceding research of personality starting from the earlier line of research of personality psychology to then continuing into the research from the field of personality neuroscience. Secondly, each of every factor of the Big Five will be described, discussed with findings of the neurobiology matching each factor - which is the main focus of this thesis. In the end, a discussion will be found with a summary of all the mentioned discoveries together with a critical analysis of their reliability and validity as well as countering studies. Considering the fact that extraversion and neuroticism appear to be more studied than the other factors of the Big Five since they appear to be long-standing traits (Adelstein et al., 2011), their sections in this thesis will be more elaborated than the remaining factors. Since this thesis has its focal point on the *neurobiology* of the Big Five, I have chosen to strictly present only articles that stick to this matter. I do have the knowledge about the widely numerous research that has declared the correlation between Big five and other domains and outcome, thus they will merely be included and not written or discussed extensively. Because of this exact reason, the outcome section might be a bit thin because of as far as my knowledge goes, there seems to be a shortage of research that touches upon the Big five and outcomes that use neuroimaging methods in their studies.

Method. The selection of articles for the thesis was primarily focused on research that included the Big Five, as well as, its outcomes, and neurobiology – in other words, studies that used neuroimaging techniques. The articles that made the cut are articles that have been cited relatively moderately, in regard to their publication year. Articles were searched for in academic databases concerned primarily with research disciplines of personality psychology, personality neuroscience, developmental psychology, cognitive neuroscience, and neuroscience. Keywords used for articles searches included; “Big Five and neurobiology”,”five-factor model”, “extraversion and neurobiology”, “neuroticism and neurobiology”, “agreeableness and neurobiology”, “conscientiousness and neurobiology”, openness to experience and neurobiology”,“Big Five and academic performance and achievement”, and “Big five and outcomes”. Secondary selections were made by tracing cited and citing articles of those from the first selection. Articles evaluated as most important for the aim of the thesis constituted the final selection.

Personality Psychology Meets Neuroscience

The field of personality psychology have for decades attempted to provide us with theories to explain the underlying of individual differences and the fundamental underpinnings of personality (McAdams & Pals, 2006). Its focus has been on the understanding of the whole person (McAdams & Pals, 2006) by looking at individuals' behavior, motivation, emotion, and cognition and seek out the explanations behind it (Allen & DeYoung, 2017). The aim of personality psychology is and has been for a long time, to find the accurate description rather than the explanation behind personality (DeYoung & Gray, 2009). The reasons behind this were 1) the shortage of research in human neuroscience and 2) the desire of personality psychology to develop a necessary system for the categorization of personality traits (DeYoung & Gray, 2009). As the research of human neuroscience together with molecular genetics began to accumulate, new possibilities were on the horizon. When neuroscience was added to the mix on the already existing explorations made by personality psychology, a novel field was developed - *personality neuroscience.*

Personality neuroscience alike personality psychology has the aspiration to understand the whole person, thus with the added premise of likewise understanding the brain on the basis that they go hand in hand (DeYoung & Gray, 2009). The understanding of the neurobiological basis of personality traits, specifically Big Five, would entail a possibility to get a wider knowledge of complex interactions between the components; genes, environment, and the brain (Allen & DeYoung, 2017; DeYoung, 2010). This insight could lead to a tracing of stable brain patterns that are involved in the production of personality (Allen & DeYoung, 2017). Therefore, this thesis will in the guidance of the Big Five attempt to accomplish these goals.

Big Five and Neurobiology

Extraversion

The factor extraversion can be seen as a higher-order trait that is composed of lower-order traits which are sociability, talkativeness, warmth, assertiveness, gregariousness, activity, excitement seeking, positive emotionality, leadership, social engagement, and dominance (Bjørnebekk et al., 2013; Cohen, Young, Baek, Kessler, & Ranganath, 2005; Costa & McCrae, 1992; Depue & Collins, 1999; DeYoung, Quilty, & Peterson, 2007). Previous studies (Blankstein, Chen, Mincic, McGrath, & Davis, 2009; Cremers et al., 2011; DeYoung et al., 2010) on extraversion have shown that there seem to be as Bjørnebekk et al. (2013) states it "a complex pattern of positive and negative correlations has been reported between extraversion and cortical thickness in ventral, medial and lateral prefrontal regions" (p.195). A moderately sized study (n=65) by Cremers et al. (2011) using Magnetic Resonance Imaging (MRI), showed that extraversion had a positive correlation with regional brain volume in the medial orbitofrontal cortex (OFC) bilaterally with extension to the subgenual anterior cingulate cortex and the amygdala. These regions have been speculated to be involved in affective processing (Cremers et al., 2011). The medial OFC has especially been associated with behavior related to controlling reward and punishment, emotion regulation, approach-related behavior and decision making (Cremers et al., 2011). Furthermore, the OFC has projections structures such as the ventral striatum, amygdala, hypothalamus, periaqueductal grey, and hippocampus (Cremers et al., 2011). These mentioned regions have been associated with behavior modulation and the expression of emotion (Cremers et al., 2011). These results according to Cremers et al. (2011) may indicate increased sensitivity to positive, pleasant information and social reward, and thus, the propensity to experience the positive effect since the increased volume of the medial OFC and the amygdala have been associated with these functions. Extraversion as well could be characterized by these descriptions (Cremers et al., 2011). Moreover, a correlation between low extraversion and smaller right amygdala volume was also found. The findings linking the OFC with extraversion is strengthened through findings from Omura, Todd Constable, & Canli (2005) who used MRI and had 41 participants. They found a positive correlation between extraversion and gray matter concentration of bilateral OFC. Their study also found a positive correlation between extraversion and gray matter concentration in the left amygdala (Omura et al., 2005).

Further correlation between amygdala activation and extraversion have been shown by Canli (2002) using functional magnetic resonance imaging (fMRI) with 14 participants, who found a significant correlation between participants with high scores on extraversion and the amygdala activation of happy faces. Amygdala, as we know, is a crucial structure in the processing of emotional signals, content, stimuli (Koelsch, Skouras, & Jentschke, 2013) and emotional learning (Aghajani et al., 2013). Implications from these findings would be that high scores in extraversion have an imminent link with the amount of amygdala activation in the exposure of positive stimuli (Canli, 2002). However, this study had a sample size of 14 participants which makes the findings questionable. Another study (n=14) using fMRI viewing personality influences on brain reactivity to emotional stimuli found a correlation between extraversion and the levels of activation in several cortical and subcortical brain regions during the exposure of positive stimuli (Canli et al., 2001). The respective brain regions were; the left middle frontal gyrus with neighboring clusters, and the temporal cortex in the right hemisphere (Canli et al., 2001). These findings could add up to the existing notion of the connection between the trait positive emotionality of extraversion and numerous brain regions (Canli et al., 2001). Nevertheless, the sample size is of this study is also small, making the findings questionable as well.

In a study (n=28) using fMRI conducted by Wright et al. (2006), the results showed a positive correlation was found between extraversion and the lateral and medial Prefrontal cortex (PFC), including the cingulate gyrus and the amygdala in response to positive stimuli. Their results also showed a positive correlation with participants who identified themselves as extraverts and thinner cortical gray matter ribbon in regions of the right inferior PFC and fusiform gyrus (Wright et al., 2006). Considering the sample size, the findings should be taken cautiously.

Multiple studies point out that the OFC, amygdala, and additionally the nucleus accumbens - located in the basal forebrain - is associated with rewards and rewards motivation and it has also evidently been shown that dopamine is connected to the reward system (Breiter & Rosen, 1999; Cohen et al., 2005). The traits social engagement and positive emotions (traits of extraversion) have been suggested to be derived from sensitivity to cues of rewards and motivation to obtain future rewards (Depue & Collins, 1999; Cohen et al., 2005). This could imply that dopamine is an essential element in the factor extraversion (Cohen et al., 2005; Depue & Collins, 1999). As a matter, in fact, this connection has been presented by Depue and Collins (1999), who states that differences in the efficacy of dopaminergic inputs from regions such as the nucleus accumbens, the OFC, and the amygdala are linked to individuals' differences in reward sensitivity.

Numerous lines of evidence have emerged from studies resting-state functional connectivity (RSFC), this is a process which discovers patterns of synchrony of activation throughout the brain while people relax in an MRI (Oleynick et al., 2017). Amongst them is a study (n=50) by Aghajani et al. (2013) which revealed an association between increased RSFC of the right amygdala with the insula and putamen, the left amygdala with the putamen, temporal pole, insula, and several regions within the occipital cortex with high scores in extraversion. The amygdala and the putamen are known beforehand to be involved in a neural circuit which is believed to be responsible for reward processing (Haber & Knutson, 2010) and emotional learning (Aghajani et al., 2013; Canli et al., 2001). According to Aghajani et al., (2013) this would entail that "participants with higher extraversion scores may thus suggest n enhanced functional integrity of the reward circuitry in extraverts." (p.8). A small study (n=18) investigated the RSFC discovered a positive correlation with blood flow in the regions of the anterior cingulate gyrus, right insular cortex, bilateral temporal lobes, and the posterior thalamus and high scores on extraversion (Johnson et al., 1999). According to Johnson et al. (1999), these findings suggest that individuals that, scores high on extraversion have a high drive for sensory and emotional stimulation. The reason for that being the thalamus is known for handling sensory information and activity in the posterior insula have been suggested to administrate the interpretation of current sensory information (Johnson et al., 1999). Expressly, Johnson et al. (1999) state "Changes in the activity of the thalamic nuclei have the potential to decrease or increase the amount of information reaching cortical regions (p. 4). While for people with low scores on extraversion, higher blood flow was found in the regions of the lateral part of the frontal cortex, Broca’s area, the insular cortex, the right temporal cortex, and the anterior nucleus of the thalamus (Johnson et al., 1999). Since this finding regarded mostly the bilateral frontal lobe regions, this suggests that individuals with low extraversion tend to be more engaged in frontally based cognition e.g. problem solving (Johnson et al., 1999).

In a study (n=20), using positron emission tomography (PET) scan to examine the resting regional cerebral glucose metabolism of neuroticism and extraversion, it was found that extraversion had a correlation with glucose metabolism in the OFC (Deckersbach et al., 2006). These regions have been indicated to be involved in multiple mental disorders such as anxiety, OCD, post-traumatic stress disorder (PTSD) and depressive and bipolar disorders (Deckersbach et al., 2006). But the sample size of this study is quite small, thus more research this to be done on this matter.

Conclusively, extraversion has been found to correlate with brain volume and activity in regions of the OFC, areas of the temporal cortex, and amygdala and other subcortical parts. The findings regarding the amygdala seem to be conflicting since some studies found correlations with only the left amygdala while others found correlations bilaterally. As for some subcortical parts, some studies found correlations with extraversion while others failed to do so. However, those studies which found a correlation with the amygdala bilaterally and the subcortical regions had small sizes which makes their results doubtful. The correlation between extraversion and subcortical regions needs to be looked into further with larger sample sizes, in order for a valid correlation to be confirmed.

Neuroticism

The factor of neuroticism has often been associated with dimensions of negative emotions, anxiety, depression, anger, irritation, self-consciousness and vulnerability (Bjørnebekk et al., 2013; Costa & McCrae, 1992; DeYoung et al., 2007; DeYoung & Gray, 2009) as well as impulsivity (Bjørnebekk et al., 2013; Costa & McCrae, 1992), harm avoidance and vulnerability to stressors, and emotional instability (Bjørnebekk et al., 2013). Neuroticism, as opposes to extraversion, is characterized by negative affect and a proneness for sensitivity to punishment and threats (DeYoung, 2010; DeYoung et al., 2010). People with high scores on neuroticism tend to have as Allen and DeYoung (2017), propose "Defensive responses to uncertainty, threat, and punishment." (p.13). The factor neuroticism has frequently been tied to being at risk for psychopathology and mood disorders (Wright et al., 2006) and due to that fact it has been more neuroscientific research of this factor than any of the other Big Five factors (Allen & DeYoung, 2017).

One study (n=265) done with multimodal imaging examining neuroticism found a correlation between high neuroticism and reduced frontotemporal cortical surface area (Bjørnebekk et al., 2013). More specifically, this reduction of cortical surface area was found in the parts of the medial OFC extending to the frontal pole, the anterior cingulate and middle frontal areas (Bjørnebekk et al., 2013). Additionally, a correlation was found between higher neuroticism and decreasing fractional anisotropy (FA) reduced intracranial volume (ICV) and total brain volumes, the reduced cortical surface area in frontotemporal regions, and decreased white matter microstructure in brain regions (Bjørnebekk et al., 2013).

This discovery is in line with results from another study (n=116) using MRI, where it was found that high levels of neuroticism correlated with reduced volume in dorsomedial PFC and a segment of left medial temporal lobe including the posterior hippocampus (DeYoung et al., 2010). The results also showed a correlation between high neuroticism and increased volume, gray- and white matter in the mid-cingulate gyrus (DeYoung et al., 2010). Since a smaller volume in the hippocampus has been shown to be linked with depression (DeYoung et al., 2010), the assumption of the correlation between hippocampus and neuroticism become a clearer probability. The midcingulate gyrus has been associated with error detection (Carter et al., 1998) which shows that correlation between this area and higher neuroticism would indicate a higher sensitivity for conducting errors (DeYoung et al., 2010). Then we have the dorsomedial PFC which have been suggested to be involved in the evaluation of oneself and in emotional regulation (DeYoung et al., 2010). This implies that individuals with high neuroticism and a smaller dorsomedial PFC are more likely to engage in negative self-evaluation and have a dysfunctional emotional regulation (DeYoung et al., 2010).

A study (n=39) using RSFC to localizing personality in the brain found that neuroticism was correlated with the dorsomedial PFC and a significant correlation was also found in the middle temporal gyrus, and the temporal pole (Adelstein et al., 2011). As mentioned earlier, the dorsomedial PFC has been implied to be involved in self-evaluation and emotional regulation and in relation with neuroticism is suggested to lead to negative self-referencing and dysfunctional emotional regulation (DeYoung et al., 2010). As for the finding regarding middle temporal gyrus, and the temporal pole, it has been implicated that these regions are involved in fearful anticipation and negative emotion (Adelstein et al., 2011; Kumari et al., 2007). This assumption was shown by Kumari et al., (2007) who found a positive correlation between individuals with high neuroticism and their levels of fear while anticipating an electrical shock. The temporal lobe as we know, include the hippocampus (DeYoung et al., 2010) therefore it would be appropriate to consider that the results found above include the hippocampus. Which would infer that these results strengthen the findings of the link between neuroticism and depression (DeYoung et al., 2010). The temporal pole is also believed to be in involved in the perception of emotional facial expressions (Jimura, Konishi, & Miyashita, 2009). In an fMRI study (n=34) investigating the activity of the temporal pole and the perception of sad faces, the results showed that there was a correlation between the temporal lobe, the scores of neuroticism, and the perception of sad facial expressions over any facial expressions (Jimura et al., 2009). These findings are in line with the findings of Adelstein et al. 2011, showing that there might be an association between negative emotional judgment and neuroticism and also a link between neuroticism and the temporal cortex, notably the temporal pole (Adelstein et al., 2011; Jimura et al., 2009).

Previous studies can tell that intensified sensitivity to threatening stimuli can be seen as a feature of anxiety disorders, which is often treated with serotonin-potentiating drugs, such as selective serotonin reuptake inhibitors (SSRIs) (Cools et al., 2005). The amygdala has been recognized as the primary basis for the processing of threating stimuli (Cools et al., 2005). Hence, the assumption would be that the amygdala and serotonin have a connection. And as formerly acknowledged, neuroticism is related to enhanced threat sensitivity and therefore it would be reasonable to look into the relationship of amygdala and serotonin and its link to neuroticism. In a study by Cools et al., (2005) using tryptophan depletion (tryptophan depletion can induce cerebral serotonin depletion) to analyze the brain activation to fearful faces showed that tryptophan depletion caused a modulation in self-reported threat sensitivity in the amygdala and the hippocampus. This finding was supported by a large MRI study (n=1050) conducted by Holmes et al. (2012) who found a positive correlation between neuroticism and the volume of the amygdala and hippocampus.

Studies have shown that neurotransmitters and genetic factors such as polymorphisms have an impact on personality outcomes, in this case the neurotransmitter serotonin and neuroticism (Lesch et al., 1996; Takano et al., 2007) The neurotransmitter serotonin (5-HT) and serotonin transporter system (5-HTT) has been acknowledged to play a role in both physiological functions; motor activity, intake of food, regulation of sleep, and reproductive activity as well as in cognitive functions; emotional regulation and emotional states which include mood and anxiety (Lesch et al., 1996). Low levels of serotonin have been shown to be associated with aggression, poor impulse control, and depression (DeYoung, 2010). Lesch et al. (1996) found in a study with 505 participants, that the expression of the 5-HTT was depending on a length of the polymorphism that goes under the name of the 5-hydroxytryptamine (5-HTTLPR) and this polymorphism comes in two versions, one long 5-HTTLPR-L, and one short one 5-HTTLPR-L. The interesting thing about 5-HTTLPR is that the short version 5-HTTLPR-S has a connection with males with self-reported high scores on neuroticism (Lesch et al., 1996). In other words, this study showed that males who carried 5-HTTLPR-S were more like to have a higher score on the neuroticism scale than those who carried 5-HTTLPR-L (Lesch et al., 1996). They also find that men who carried 5-HTTLPR-S and had increased neuroticism seemed to have a reduced capacity for the uptake of 5-HT, which would suggest that there is a link between decreased uptake of 5-HT and higher scores on neuroticism (Lesch et al., 1996). Note that, this study was conducted on primary men and therefore the generalization would only apply to such degree. There were other findings in this study that had a correlation with this polymorphism, specifically agreeableness (Lesch et al., 1996) - another factor of the Big Five - that will be discussed in later in the next section.

A more recent replication study (n=397) was done in 2000 by Greenberg et al., who examined the role of this polymorphism in the female population and even here a correlation between the polymorphism and neuroticism was found. The study was conducted using 397 participants whereof 84% were women and here the results showed that there seemed to also be a correlation between the 5-HTTLPR-S genotype and an increasing in the rates of depression and hostility - which goes under neuroticism (Greenberg et al., 2000). Whilst there seemed to be no correlation found between the facet of anxiety and this genotype as in the previous study (Greenberg et al., 2000; Lesch et al., 1996). This raises the question of whether there could be a difference in gender and serotonin functioning because of the different findings, which the authors give the suggestion of that it could be a possibility thus other lines of research have shown that this polymorphism has the same expression regardless of gender (Greenberg et al., 2000).

Gathering this information, the implication would be that the 5-HTTLPR-S genotype has a connection with neuroticism generalizing to both genders (Greenberg et al., 2000). Considering, the 5-HTTLPR polymorphism's involvement in the processing of serotonin, there seems to be a relation between the mentioned neurotransmitter and neuroticism as well (Greenberg et al., 2000).

Neuroticism and Neuropsychological Disorders. Personality traits have been said to be one of the major factors contributing to the vulnerability of depression (Takano et al., 2007). Depression has been suggested to be a facet of neuroticism (Bjørnebekk et al., 2013; Costa & McCrae, 1992; DeYoung et al., 2007; DeYoung & Gray, 2009) hence the correlation between the two of them is highly likely. It has also been suggested that anxiety-related personality traits are about 50% heritable (Lesch et al., 1996). Studies that have shown the correlation between neuroticism and several neurological disorders using DSM-criteria; Krueger, McGue & Iacono (2001), Khan, Jacobson, Gardner, Prescott, & Kendler (2005), Chien, Ko, & Wu (2007).

In the study by Bjørnebekk et al. (2013), a negative correlation was found between neuroticism and the lateral temporal lobe including supramarginal gyrus in the parietal lobe. These findings according to Bjørnebekk et al., (2013), were the most connected to the dimensions; anxiety, depression, and vulnerability to stressors. Reductions in the abovementioned brain regions have been consistently demonstrated to be linked to PTSD, which would indicate that there might be a relation between neuroticism and the risk of PTSD (Bjørnebekk et al., 2013). Other than depression, anxiety has also been suggested to be associated with neuroticism (Costa & McCrae, 1992; DeYoung et al., 2007; DeYoung & Gray, 2009). Neuroticism has been associated with the short version of the polymorphism – referred to as the 5-HTTLPR-s - of the serotonin transporter gene (Greenberg et al., 2000; Lesch et al., 1996). More specifically, the correlation was regarded to the anxiety facet of neuroticism which gives an indication of a correlation between neuroticism and anxiety disorders (Lesch et al., 1996). In addition, it has been suggested people with this short version of 5-HTTLPR display greater neuronal activity the amygdala in response to threatening visual stimuli (Hariri et al., 2002; Pezawas et al., 2005). As we know, the amygdala is involved with emotion and mood processing (Aghajani et al., 2013; Canli et al., 2001; Koelsch et al., 2013) it has been implicated to be related with mood disorders (Hariri et al., 2002; Pezawas et al., 2005). In the study mentioned above, by Deckersbach et al. (2006), it was shown that neuroticism had negative correlations with glucose metabolism in regions of the insular cortex. These regions have been indicated to be involved in multiple mental disorders such as anxiety, OCD, PTSD and depressive and bipolar disorders (Deckersbach et al., 2006). Furthermore, neuroticism has been stated to be a major personality risk factor for psychopathology (Wright et al., 2006).

However, the existing neuroimaging studies are slim, henceforth more research is needed.

Agreeableness

Agreeableness is composed of facets such as; trust, straightforwardness, altruism, compliance, modesty, and tender-mindedness (Bjørnebekk et al., 2013; Costa & McCrae, 1992; DeYoung et al., 2010) as well as warmth, understanding, empathy, pleasantness, morality, politeness, and modesty (DeYoung et al., 2007; DeYoung & Gray, 2009). Hu et al., (2011,) asserted that "Agreeableness represents the most humane aspect of humanity—characteristics such as altruism, nurturance, caring, and emotional support." (p. 1). People with high scores rating on agreeableness tend to lean toward more altruistic and social cooperative behavior rather than deceitful and antisocial behavior (Allen & DeYoung, 2017; DeYoung, 2010; DeYoung & Gray, 2009). According to DeYoung (2010), agreeable people reflects a tendency to care for other people's needs, desires, and feelings which then indicates a capacity for understanding how other people feel, their motives, and their mental states. Furthermore, people with high scores on agreeableness tend to avoid conflicts and are prone to inhibit their on aggression and comply to others will instead of their own in order to avoid disagreement (Bjørnebekk et al., 2013; DeYoung, 2010). The opposite trait of agreeableness would be Antagonism which is characterized with facets of aggression and callousness (DeYoung et al., 2010). Agreeableness has also been linked with the ability to regulate or suppress aggressive impulses and other socially disruptive emotions (DeYoung, 2010). The research of the factor agreeableness appears to be lacking, inclusive, and least developed in comparison to the other factors of the Big Five (Bjørnebekk et al., 2013; Lewis et al., 2016; Nettle & Liddle, 2008) nonetheless there is still a growing number of studies that can be presented.

Since the facets of agreeableness include traits of which display theory of mind, empathy, prosocial behavior it would be adequate to hypothesize that there is a link between agreeableness and brain areas that are involved in these functions (DeYoung, 2010; DeYoung et al., 2010). The brain regions that are associated with these functions are suggested to be the superior temporal sulcus, temporoparietal junction, fusiform gyrus, and posterior cingulate cortex (DeYoung, 2010; DeYoung et al., 2010) and the areas of right medial temporal and orbitofrontal areas, and left medial frontal areas considering the fact that these areas have been implied to be involved in theory of mind (Nettle & Liddle, 2008). These findings are supported by findings from a large-scale study (n=108) using MRI done by Li et al. (2017) who found a significantly positive correlation between the surface area of the superior temporal gyrus and agreeableness. The superior temporal gyrus has been suggested to be involved in the process of interpreting how others act and their intentions which are a function of the theory of mind (DeYoung et al., 2010; Li et al., 2017). Furthermore, it has been shown that the superior temporal gyrus is involved in emotional processing and effective responses to social cues, such as facial expressions and eye direction (Li et al., 2017). Li et al. (2017), also found a correlation between decreased sulcus of the superior parietal lobe and agreeableness. Alteration in structures of the superior parietal lobe has been associated with cluster B personality disorders which indicates that the superior parietal lobe has a suggested involvement in the integration of some emotional and cognitive functions, such as sensory information and processing (Li et al., 2017).

In a big scale study (n=116) using MRI conducted by DeYoung et al. (2010), a positive correlation between the retrosplenial region of posterior cingulate cortex and the fusiform gyrus and agreeableness was found. Additionally, a negative correlation between agreeableness and the superior temporal sulcus and the adjacent superior temporal gyrus was also discovered (DeYoung et al., 2010). To be more specific, the correlations showed that higher agreeableness was linked with a decreasing volume in the posterior left superior temporal sulcus and with increased volume in the posterior cingulate cortex (DeYoung et al., 2010). The findings also showed that there seemed to be a correlation between larger brain tissue volume in the fusiform gyrus and the score of agreeableness (DeYoung et al., 2010). The fusiform gyrus is believed to be involved in the processing of social information which is in line with many facets of agreeableness (DeYoung et al., 2010). According to DeYoung et al. (2010), the results regarding the superior temporal sulcus are counterproductive to the hypothesis of the neurobiological basis of agreeableness because of the functioning of this area.

In another MRI study (n=87) conducted by Kapogiannis, Sutin, Davatzikos, Costa, & Resnick (2012) looking at the relationship between gray matter (GM) volume in brain regions and the Big Five found that agreeableness correlated both positively and negatively with GM volume in certain brain areas. Their results showed that there was a positive correlation between agreeableness and GM volume in the right OFC, the middle temporal pole, and the superior parietal cortex (Kapogiannis et al., 2012). A negative correlation was found between agreeableness and GM volume in the bilateral dorsomedial prefrontal cortex - superior medial frontal gyrus, in the left dorsolateral prefrontal cortex -

middle frontal gyrus, in the left parahippocampal gyrus, in the right calcarine, and in the left superior temporal gyrus - Wernicke's area (Kapogiannis et al., 2012). The right OFC has been implied to be a critical area in functions such as; social and moral cognition which is line with agreeableness since its facets include social and moral tendencies (Kapogiannis et al., 2012).

In a RSFC neuroimaging study (n=49) using fMRI conducted by Sampaio, Soares, Coutinho, Sousa, & Gonçalves (2014) examining the correlation of the Big Five and the Default Mode Network (DMN) it was shown that agreeableness had an association with the medial prefrontal cortex (mPFC) and the anterior cingulate cortex (ACC). The DMN can be described as a network of various brain areas that produce high metabolic activity when the brain is at "rest" (Sampaio et al., 2014). These areas are known to include the posterior cingulate cortex and adjacent precuneus, the medial prefrontal cortex, medial-, lateral- and inferior parietal cortex, and medial temporal cortex (Sampaio et al., 2014). This network have been suggested to be in charge in functions such as; social awareness, the capability to assign mental states to others, internal mental activity, autobiographical memory, the integration of emotional and cognitive processing, and connecting internal and external attention in monitoring the world around us (Sampaio et al., 2014). This further the hypothesis of agreeableness to be linked with the theory of mind, empathy, and prosocial behaviors (Sampaio et al., 2014). Furthermore, the results showed that increased activity in the right superior parietal cortex was correlated with decreasing scores in agreeableness (Sampaio et al., 2014). The right superior parietal cortex has been implicated to be responsible for the response to negative pictures and meaning (Sampaio et al., 2014).

Haas, Omura, Constable, & Canli (2007) did an fMRI study (n=48) investigating the relationship between emotional regulation and agreeableness, in which they found a correlation between the right lateral prefrontal cortex (RLPFC) activation in the processing of fearful facial expressions and the scores of agreeableness. The RLPFC has been associated with emotional regulation, particularly negative effect (Haas et al., 2007). Since there seems to be a correlation between this area and agreeableness, there is a probability that agreeableness could be tied with the mediating of negative affect regulation (Haas et al., 2007). Another RSFC study (n=39) using fMRI made by Adelstein et al. (2011), found that agreeableness had a positive correlation with the posteromedial extrastriate regions and some areas of the primary sensorimotor. These areas are according to Adelstein et al. (2011) involved in attention that revolves around the social or emotional activity.

In the study (n=505) by Lesch et al. (1996), a negative correlation was found between agreeableness and the 5-HTTLPR genotype, this finding was however only found when combining all the samples and not significant in the smaller group samples. Furthermore, Greenberg et al. (2000) found that people with the 5-HTTLPR-S genotype had a lower score on agreeableness and a negative correlation between the agreeableness facets of straightforwardness and compliance and the 5-HTTLPR-S genotype was also found.

Oxytocin and testosterone are other psychoactive substances that have been associated with agreeableness (Allen & DeYoung, 2017; DeYoung & Gray, 2009). According to DeYoung & Gray (2009), oxytocin has a key role in social bonding henceforth the association is quite capable since agreeableness is heavily linked with prosocial behavior and facets. Testosterone, on the other hand, have been suggested to be linked to aggression and preceding research have shown that higher exposure to testosterone leads to decreased agreeableness (Allen & DeYoung, 2017; DeYoung, 2010; DeYoung & Gray, 2009).

Some studies found negative correlations with agreeableness and parts of the superior temporal gyrus and sulcus while others found positive correlations, hence the relation between this region and agreeableness needs to be looked into further.

Conscientiousness

Conscientiousness consists of facets such as self-control, motivation, decisiveness, responsibility towards others, hard work, task- and goal-oriented behavior, order, and following rules (Bogg & Roberts, 2004; Costa & McCrae, 1998; Roberts et al., 2014). According to Roberts et al. (2014), the factor conscientiousness can be used to predict extensive preventative and risky behaviors for both physical health and mortality. Moreover, conscientiousness can predict health as well as educational, and personnel psychology outcomes (Bogg & Roberts, 2004; Poropat, 2009; Roberts et al., 2014). Conscientiousness has been widely associated with workplace performance along with academic performance (which will be discussed later in the thesis) (Bogg & Roberts, 2004; Poropat, 2009; Roberts et al., 2014). It has also been shown to be the most reliable predictor when it comes to marital stability, leadership, income, and occupational attainment (Roberts et al., 2014).

Serotonin is a neurotransmitter that has been positively linked to conscientiousness considering the functions of serotonin - low serotonin has shown to lead to anxiety, depression, aggression and poor impulse control (DeYoung & Gray, 2009; Spoont, 1992). This correlation was shown further in the study (n=119) by Manuck et al. (1998) who used pharmacological manipulation to manipulate the serotonin release and inhibits reuptake and found a positive correlation between conscientiousness and serotonergic responsiveness.

DeYoung et al. (2010) propose that it is likely that conscientiousness is tied to the PFC, due to the functions of the PFC which have been suggested to be the ability to plan and follow complex rules. This was found to be probable in a study (n=116) using fMRI by DeYoung et al. (2010) which showed that conscientiousness was positively correlated with volume in a region of lateral PFC and in most parts of the left middle frontal gyrus. The middle frontal gyrus has been associated with the functions of maintaining information in working memory and in the execution of planned action (DeYoung et al., 2010).

In an fMRI study (n= 79) examining the relationship between personality and aging done by Jackson, Balota, & Head (2011), it was found that conscientiousness had a positive association with orbitofrontal volumes which strengthens the hypothesis of the relationship between the PFC and conscientiousness. Furthermore, it was shown that the brain volumes in cerebral white matter, amygdala, and the parahippocampal decreased with age in people with lower conscientiousness (Jackson et al., 2011). This was supported by results from another study which found a positive correlation between conscientiousness and gray matter volume in multiple frontal areas; superior frontal gyrus, right postcentral gyrus, left precuneus, right inferior frontal gyrus, pars opercularis, right superior temporal gyrus, right precentral and left superior frontal gyri, left anterior cingulate, left caudate nucleus, left lingual gyrus, and left hippocampus (Kapogiannis et al., 2012). Moreover, a negative correlation was also found between conscientiousness and gray matter volume within the right middle temporal pole, left superior temporal gyrus, bilateral frontopolar cortex, left superior parietal lobule, left calcarine, right postcentral gyrus, and right medial orbitofrontal cortices (Kapogiannis et al., 2012).

This line of evidence is aligned with the hypothesis that there is a correlation between facets of conscientiousness and the goal priority network (Allen & DeYoung, 2017; Rueter, Abram, MacDonald, Rustichini, & DeYoung, 2018). The goal priority network is a wide network which includes the ventral attention network and the salience network - which are located in the dorsolateral PFC region. In a large (n=218) resting-state fMRI study analyzing the RFSC of the Big Five, it was found that conscientiousness was positively correlated with the dorsal anterior cingulate cortex (dACC), anterior insula, and middle and superior frontal gyri which all is located in the region of the dorsolateral PFC (Rueter et al., 2018).

Conscientiousness and Academic Achievement and Performance. Finding out which Big Five factors or which of its hierarchy of traits is the probable predictors of academic achievement and performance could lead to important implications for learning and education (O'Connor & Paunonen, 2007). This knowledge could lead to the possibility to develop curricula which purpose is to improve the levels of academic performance for most (O'Connor & Paunonen, 2007). Academic performance is often measured with grades and grading point average (GPA) (Poropat, 2009). Nevertheless, GPA as a measurement for academic performance has been questioned since it might not be the most reliable because of grade inflation (Poropat, 2009). The most eminent and consistent factor that has been associated with academic performance and achievement is conscientiousness (Chamorro-Premuzic & Furnham, 2003a; Chamorro-Premuzic & Furnham, 2003b; Costa & McCrae, 2008; O'Connor & Paunonen, 2007; Poropat, 2009). Nonetheless, the other factors should not be ruled out entirely considering the existence of both negative and positive correlation between some of them and academic performance and achievement. The main reason for the correlation between academic performance and achievement and conscientiousness has been noted to be motivation and since motivation is one of the facets of conscientiousness this correlation is feasible (O'Connor & Paunonen, 2007). However, the other facets such as organized, hardworking, and goal-oriented have been suggested to be the key to perform better at academic tasks (O'Connor & Paunonen, 2007).

There are broadly various studies that have used psychometric tasks and scales or mainly GPA as a method of comparison that has found a correlation between conscientiousness and academic achievement and performance; Chamorro-Premuzic and Furnham (2003a) Chamorro-Premuzic and Furnham (2003b), Furnham, Chamorro-Premuzic, and McDougall (2003), and Lievens, Coetsier, De Fruyt, and De Maeseneer (2002).

In a resting-state fMRI study (n=22) examining university professors with high academic achievement compared to university professors with low academic achievement, a large gray matter volume was found in the OFC of the high achievement professors (Li et al., 2015). The OFC has been suggested to be involved in motivational control of goal-directed behavior (Li et al., 2015) which fits perfectly with the domains of conscientiousness (Allen & DeYoung, 2017; Rueter et al., 2018). Moreover, the OFC and conscientiousness have formerly been associated (Jackson et al., 2011; Kapogiannis et al., 2012) which strengthens the assumption of the correlation between conscientiousness and academic achievement and performance. The level of achievement was distinguished on their number of published research papers indexed in Science Citation Index (SCI) and China National Knowledge Infrastructure (CNKI) (Li et al., 2015).

In consideration of the lack of studies on both conscientiousness and conscientiousness and academic achievement and performance, more research is needed in order for any correlations to be made.

Openness to experience/Intellect

Openness to experience/Intellect (can also be called Openness/Intellect for short) includes domains such as fantasy, feelings, actions, aesthetics, ideas, and values (Costa & McCrae, 1992; Johnson, 1994) along with quickness, creativity, ingenuity, competence, depth, introspection, imagination, and reflection (DeYoung et al., 2007) and in addition to intellectual curiosity, intellectual interests, perceived intelligence, artistic interests, emotional richness, and unconventionality (Kaufman et al., 2015). In fact, "openness is seen in the breadth, depth, and permeability of consciousness, and in the recurrent need to enlarge and examine experience." (McCrae & Costa, 1997, p.826). According to DeYoung (2014), openness/intellect are made of processes which go under the domain of cognitive exploration. These processes reflect as DeYoung (2014) states it "individual differences in the ability and tendency to seek, detect, comprehend, utilize, and appreciate complex patterns of information, both sensory and abstract." (p. 2). Openness to experience/Intellect can also be referred to as Intellect alone or just Openness to experience. The labeling of this factor is an ongoing debate in the field of both personality psychology and personality neuroscience (DeYoung, Peterson, & Higgins, 2005). In this thesis the label Openness/intellect due to the reasoning that this labeling gives a broad description of the two different aspects of this factor. Openness/intellect have been shown to be able to predict outcomes such as; creative achievement and divergent thinking, creative hobbies, personal goals, and thinking styles (Feist, 1998; Kaufman et al., 2015) as well as personal health - mental and physical, proneness to neurological disorders, academic and work achievement, and social behavior (Ozer & Benet-Martínez, 2006).

Openness/intellect has been associated as the predictor of trait creativity, mainly due to the fact that they share various common domains (Batey & Furnham, 2006; Feist, 1998; King, Walker, & Broyles, 1996; Li et al., 2014; McCrae, 1987). Furthermore, it has consistently been found to be positively linked with intelligence (DeYoung, 2010; DeYoung et al., 2005). General, crystallized, and fluid intelligence has been suggested to be related to the cortical thickness and functions in networks of the regions such as frontoparietal and temporal cortices (Choi et al., 2008). General intelligence has been described as general mental ability, crystallized intelligence as verbal ability along with semantic memory and long-term knowledge storage, and fluid intelligence refers to one's ability to reason which relies on the working memory (Choi et al., 2008).

DeYoung et al. (2010) found in an MRI study (n=116), that a region of the parietal cortex which has its involvement in controlling attention and working memory was linked with openness/intellect. This region has been suggested to be strongly correlated with intelligence (DeYoung et al., 2010). Adelstein et al. (2011) found in an RSFC study (n=39) using fMRI, a positive correlation between openness/intellect and functional connectivity in the dorsolateral PFC region, a region that has been linked with working memory, intelligence, creativity, and the intellect. The domains of these regions are similar to those of openness/intellect which gives the implication that the dorsolateral PFC might have a correlation (Adelstein et al., 2011). In line with this finding, Xu & Potenza (2012) found in a diffusion tensor imaging (DTI) study (n=51), that openness/intellect had a positive correlation with white matter integrity in the dorsolateral PFC bilaterally. The results also showed a positive correlation between openness scores and the white matter integrity in areas such as the anterior cingulum, forceps minor, corpus callosum, corona radiata, superior longitudinal fasciculus, and inferior frontal occipital fasciculus which indicates that openness has an association with cortical and subcortical networks (Xu & Potenza, 2012). This implies that the assumption of that openness/intellect being associated with intelligence is likely since the cortical and subcortical network regions of intelligence resemble those of openness (Xu & Potenza, 2012).

Moreover, openness/intellect was found to be linked with increased functionality in the midline hubs of the DMN (Adelstein et al., 2011). Besides earlier mentioned functions, the DMN is also known for its involvement in the integration of the self and the environment (Adelstein et al., 2011). In line with this finding, it was found in another study that openness/intellect scores were correlated with increased activity in the inferior parietal lobe (Sampaio et al., 2014). The factor was also found to be negatively correlated with activity in the bilateral superior parietal cortex and left precuneus which is suggested to signify the capacity to process social, emotional, and sensorial stimuli (Sampaio et al., 2014). Another correlation between openness/intellect and the right inferior parietal lobule was found in an MRI study (n=274) measuring the annual rate of change in regional gray matter volume (Taki et al., 2012). Meaning that participants who had lower scores in openness/intellect had accelerated loss of gray matter in the right inferior parietal lobule compared to those with higher scores (Taki et al., 2012). In a study examining the relationship between global efficiency of the DMN and the Big Five, it was shown that higher score on openness/intellect correlated with the increased efficient functioning of the DMN (Beaty et al., 2015). Beaty et al. (2015) conducted a resting-state fMRI study (n=117), examining the dynamic functional connectivity of the DMN and openness/intellect and found a positive correlation between openness/intellect and right dorsolateral PFC and anterior and posterior regions of the DMN in cooperation. Since the right dorsolateral PFC has been associated as a cognitive and executive network with facets of e.g intelligence and creativity and openness/intelligence share the same domains, this finding further supports the correlation (Adelstein et al., 2011). Both openness/intellect and the DMN has the trait imagination as their central domain which could be the reason for the association between them (Beaty et al., 2015; DeYoung, 2014).

As mentioned earlier, openness/intellect is the factor that have been widely associated with creative expression and exploration (Batey & Furnham, 2006; Feist, 1998; King et al., 1996; Li et al., 2014; McCrae, 1987) which entails for both scientific and artistic creativity (DeYoung, 2014). In a DTI study (n=72), where openness/intellect was accounted as a measurement of creativity, it was shown correlations of lower white matter integrity in uncinate fasciculus and anterior thalamic radiation (Jung, Grazioplene, Caprihan, Chavez, & Haier, 2010). Negative correlations in cortical thickness in the left frontal lobe, lingual gyrus, cuneus gyrus, right angular gyrus, inferior parietal gyrus, and fusiform gyrus along with a positive correlation in the posterior cingulate gyrus and right angular gyrus (Jung et al., 2010). Reduced integration in the uncinate fasciculus and anterior thalamic radiation have been suggested to signify intelligence and creativity (Jung et al., 2010). The increased cortical thickness of the right cingulate cortex and the right angular gyrus indicates creative capacity and creative achievement while the decreased cortical thickness of the frontal and some posterior cortical regions have been associated with the generation new and original ideas (Jung et al., 2010). Although, for the cortical thickness in the regions of the occipital- and parietal cortex the correlation is yet to be determined due to the limited existent research on the matter (Jung et al., 2010).

Openness/intellect appears to have a relationship with the neurotransmitter dopamine which has been noted prior to being involved in reward (Oleynick et al., 2017). Aside from reward, dopamine has also been assessed to have a role in reduced latent inhibition, working memory, and divergent thinking (Oleynick et al., 2017) as well as in the facilitation of exploration (DeYoung, 2013). Latent inhibition is an automatic preconscious process which helps individuals to categorize stimuli as relevant or irrelevant for future associations and from that then blocks irrelevant stimuli to reach conscious awareness (Allen & DeYoung, 2017; Peterson & Carson, 2000). Since direct dopaminergic activity cannot be studied by using fMRI, it has to be studied by looking at the neural activity in the regions that have been assessed to be the dopaminergic system (Allen & DeYoung, 2017). Reduced latent inhibition has been related with increased dopaminergic activity in the mesolimbic pathways, which includes substantia nigra/ventral tegmental area projections to the ventral striatum and the OFC (DeYoung et al., 2005; Passamonti et al., 2015). Openness/intellect has however also been linked with reduced latent inhibition which indicates an interconnective relation between the three concerned parts (Allen & DeYoung, 2017; Peterson & Carson, 2000). This correlation between the three components has been suggested to imply creativity and open-mindedness (Peterson & Carson, 2000) and the automatic tendency to perceive salient information in everyday life (Allen & DeYoung, 2017). Furthermore, it was found in a relatively moderate resting-state fMRI study (n=46), that openness/intellect had a positive correlation with the functional activity in the mesocortical networks (Passamonti et al., 2015).

Discussion

The aim of this thesis has been to present evidence from the field of personality neuroscience with the focus on the neurobiology underlying personality traits with the Big

Five as a suitable model. Since the field of personality neuroscience is a more recently developed field, there is a lack of existing neurobiological studies. However, gathering all of the evidence from studies presented in this study, an array of correlation can still be drawn.

As presented in the studies above, high scores on extraversion are associated with gray matter volume, regional brain volume, and thickness in various brain regions. The correlations were for the most located in the prefrontal regions – the medial OFC, temporal areas – poles and lobes, thalamus, and subcortical areas - amygdala, putamen, caudate (Aghajani et al., 2013; Canli et al., 2001; Canli, 2002; Cohen et al., 2005; Cremers et al., 2011; Johnson et al., 1999; Omura et al., 2005; Rauch et al., 2005; Wright et al., 2006; Wright et al., 2007) The medial OFC as we know, have been associated with both general reward and social reward, punishment, rewards motivation, decision making which has a relation with dopamine (Breiter & Rosen, 1999; Cremers et al., 2011) as well as classifying for the value of rewards (DeYoung, 2010; DeYoung et al., 2010; Rauch et al., 2005; Omura, et al., 2005) and motivation for exploration (DeYoung, 2013). Looking at the facets of extraversion, these correlations might not be overly surprising. Extraverted individuals have been noted to be described with the need for exploration and seeking out excitement. This need could range to cover everything from adventures and highly stimulating activity to the exploration and rewards of socialization. Furthermore, impairment the OFC has been immensely associated with problems with reading and interpreting social signals as well as a lack of affect, and problems with decision making (Kringelbach, 2005). Since more extraverted subjects have shown greater activity in the OFC, this implies that they might be better at reading and interpreting social signals than less extraverted subjects and in additionally also experience a higher level of affect. Extroverts could also be more compelled to make more decisions than those with lower scores on extraversion. However, other studies have done the same examination between extraversion and the medial OFC and found no correlations at all (Bjørnebekk et al., 2013; Hu et al., 2011; Kapogiannis et al., 2012; Liu et al., 2013). The amygdala has widely been associated with overall emotional learning and processing and with the findings showing that there was a correlation with this region and extraversion only with positive stimuli, could be interpreted as that extraversion is linked with positive emotional processing. This indicates that more extraverted individuals have the tendency to have a greater reaction to positive stimuli than perhaps less extraverted individuals. Nonetheless, the associations between the amygdala have been conflicting. Some associations have been with the left amygdala (Omura et al., 2005) and others with the right amygdala (Cremers et al., 2011) while some found correlations with the amygdala bilaterally but only in coherence with positive stimuli (Canli, 2002; Canli et al., 2001) whereas some found no such correlation at all (Wright et al., 2006; Wright et al., 2007).

As for high scores on neuroticism, studies have shown correlations with reduced overall brain volume and in the surface area of the frontotemporal area (Bjørnebekk et al., 2013). Several negative correlations have been found between neuroticism and the dorsomedial PFC, the cingulate cortex, regions of the temporal cortex, (Adelstein et al., 2011; DeYoung et al., 2010; Jimura et al., 2009; Kumari et al., 2007) and the amygdala (Cools et al., 2005; Holmes et al., 2012). As well as associations with serotonin and a serotonin polymorphism 5-HTTLPR (Cools et al., 2005; Greenberg et al., 2000; Lesch et al., 1996). Decreased volume in the medial PFC has been associated with poorer social functioning and a higher tendency to social withdrawal along with increased errors in emotion perception (Holmes et al., 2012). This could imply that subjects with higher scores on neuroticism can experience the feelings of unease or anxiety in social context due to the decreased volume of their medial PFC. On the other hand, the increased errors in the perception of emotions could lead neurotics to perceive a higher rate of negative emotions in a social context than people with less neuroticism, leading them to be more prone to socially withdraw. As mentioned earlier, the cingulate cortex has been associated with error detection (Carter et al., 1998) which could illustrate that neurotics tend to be more likely to have an enhanced error detecting radar than people with less neuroticism. The connection between the amygdala and neuroticism could possible mean that neurotics tend to react to more negative emotions and stimuli than non-neurotics. Since neuroticism relates to 5-HTTLPR-S which has been linked with a reduced capacity for the uptake of serotonin (5-HT) and low serotonin has been associated with facets much like those of this factor, this leads to the hypothesis that neuroticism might be caused by genetics. However, this is a cautiously made hypothesis since only some of the traits have been said to be a result of genetics henceforth there could be other variables involved. Neuroticism is the factor that has been most frequently been associated as a predictor for the vulnerability of various neurological disorders. Still, the number of studies existing on this matter are rigorously limited and need to be researched further.

These findings of agreeableness were a bit scattered and inconsistent; some studies found a negative correlation with agreeableness and certain brain regions while others found a positive correlation with those regions. Li et al. (2017), found a positive correlation between agreeableness and regions of the superior temporal gyrus, while Kapogiannis et al. (2012), found a positive correlation. Henceforth, these regions need to be studied further. Agreeableness was also found to be correlated with the superior temporal sulcus, the ACC, the OFC, areas of the temporal cortex, and the medial and lateral PFC as well as the superior parietal cortex (DeYoung, 2010; DeYoung et al., 2010; Haas et al., 2007; Kapogiannis et al., 2012; Li et al., 2017; Nettle & Liddle, 2008; Sampaio et al., 2014). Some of these areas have been noted to be associated with the DMN and theory of mind which are both involved in understanding and interpreting social cues and other mental states. Agreeable people have been characterized with being caring, wanting harmony and avoiding conflict. Henceforth, being able to understand social cues and what others are thinking and feeling give agreeable people the advantage to do just that. In order to, be caring and utilize empathy one must be able to comprehend the mental states of others. By having the ability to picking up social cues with ease, agreeable people would have better insight into what to do to achieve harmony and refrain from to avoid conflict. Since oxytocin has been acknowledged to have a major role in social bonding, the correlation between it and agreeableness are highly probable. Agreeableness is all about caring for other needs and offering emotional support which would likely result in social bonding. However, some of the findings are conflicting which makes it difficult to surely pin down whether these brain areas are the neurobiological basis of agreeableness.

Conscientiousness was linked with the lateral PFC, the OFC, amygdala, right superior temporal gyrus, left anterior cingulate, left caudate nucleus, left lingual gyrus, and left hippocampus as well as the goal priority network which consists of the s the ventral attention network and the salience network (DeYoung et al., 2010; Jackson et al., 2011; Kapogiannis et al., 2012; Rueter et al., 2018). These regions are mainly located frontal parts of the brain which has been acknowledged to manage functions such as; the ability to plan, following complex rules, maintaining information in working memory, the execution of planned action as well as prioritizing goals (DeYoung et al., 2010; Rueter et al., 2018). Since the conscientious individuals are often described as hard-working, task- and goal-oriented, orderly, and rules followers this association is reasonable. Nonetheless, the research on the neurobiology of conscientiousness are somewhat slim and some of the studies had small samples which make it challenging to trust the correlations. Conscientiousness has also been associated as a predictor for academic performance and achievement (Chamorro-Premuzic & Furnham, 2003a; Chamorro-Premuzic & Furnham, 2003b; Costa & McCrae, 2008; O’Connor & Paunonen, 2007; Poropat, 2009) however, the neurobiological studies on this matter are limited which makes it hard to draw any substantial correlations. Recently, personality traits have been suggested to be an essential predictor of academic performance and achievement yet there are barely any studies on the relationship between the traits and academic success with neuroimaging as a method. With this kind of research, the questions of why and which personality traits would be the predictors could possibly be answered. This kind of research could be beneficial to many scientific fields, especially learning and education.

Openness/intellect was positively correlated with the dorsolateral PFC, the DMN, the inferior parietal lobe, posterior cingulate gyrus, right angular gyrus, and the mesolimbic pathways (Adelstein et al., 2011; Allen & DeYoung, 2017; Beaty et al., 2015; DeYoung et al., 2010; Jung et al., 2010; Peterson & Carson, 2000; Sampaio et al., 2014; Taki et al., 2012; Xu & Potenza, 2012), and negatively correlated with white matter integrity in uncinate fasciculus and anterior thalamic radiation, cortical thickness in the frontal lobe, lingual gyrus, cuneus gyrus, right angular gyrus, inferior parietal gyrus (Jung et al., 2010). These are areas that have been proposed to be related to intelligence, creativity, and exploration. High scores on openness have been associated with curiosity and imagination which makes the correlation with these areas highly possible. However, there is an ongoing debate about the domains of openness/intellect and whether openness/intellect should be studied as separate factors, hence the findings might be inconsistent. Because some findings might only regard to either the openness aspect or the intellect aspect. This creates the problem of not knowing which of the aspects these results are linked with. To sort out this confusion further neuroscientific research on factors and the facets are much needed.

Limitations and Future Directions

Through the development of neuroscience, widespread availability of new and more effective methods for studying the neurobiological basis of personality has emerged. Even though it has led to many valuable discoveries, it has also lead to methodological problems (Allen & DeYoung, 2017; Yarkoni, 2015). One of them is the sample size in many studies (Allen & DeYoung, 2017; Yarkoni, 2015), the vast majority of these studies presented had the sum of participants lower than 30, which makes their results questionable. There is a high change of Type 1 – also called false positives, meaning finding significant effects where there might not be any - because of their sample sizes. Moreover, some of the results were inconsistent with each other. The inconsistency leads to the inability to pinpoint whether certain brain region could be a neurobiological basis or not. Nevertheless, the reason for this inconstancy in the results could be due to the different uses of methods, some used neuroimaging on the whole brain, while others focused on specific areas. This makes it difficult to draw any significant correlations and generalizations. Furthermore, there seems to be disagreement in the field of personality neuroscience for which facets should be included in various factors and some facets of the factors might actually be overlapping (Jang et al., 2001). Some of the existing studies have often associated the correlations with the factor as a whole trait rather than looking at whether the correlations might purely regard one or perhaps several facets of the factor. A correlation between a neurobiological basis and merely one or two of the facets might not be enough to make it as a link for the whole factor. Additionally, more neurobiological research on the relation between the Big Five and academic performance and achievement as well as neurological disorders is necessary considering the lack of it.

Conclusion

The aim of this thesis was to describe the neurobiology underlying personality traits using the Big Five as a model, as well as investigating the neurobiological basis of the outcomes of the Big Five. The promising findings show that there seem to be a neuroanatomical basis for each factor as well as their outcomes. Nonetheless, the existing research on this matter is yet limited and more research is essential. With this in mind, the question of how we all differ from each other is still unanswered.

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