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The Dark Side of Personality: An Unsupervised Machine Learning Approach

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Abstract

Machiavellianism, subclinical narcissism, and subclinical psychopathy are the three aggressive and antisocial yet non-clinical personalities that were coined as a Dark Triad. Although their distinct origins, the Dark Triad shares several similar characteristics: malicious nature with varying degrees of self-promotion, emotional coldness, deception, and aggression. Few univariate neuroimaging studies, predominantly voxel-based-morphometry (VBM), have focused on the Dark Triad characteristics separately, producing contradictory conclusions of distinct structural and functional changes related to the Dark Triad. Due to the limitations of univariate methods such as VBM, as well as the fact that the majority of anatomical findings examining individual members of the Dark Triad utilize VBM, we selected source-based morphometry (SBM), which is a type of unsupervised machine learning capable of identifying homogeneous clusters and successfully identifying dispersed patterns of grey matter concentration (GMC). For the first time, our study aims to identify spatially independent GMC that predict the overall Dark Triad and separate these components in terms of the Dark Triad subscales. Our results suggest that Dark Triad traits such as violence, antisocial behavior, moral violations, and empathy impairments are closely linked with GMC variations in several subsystems (IC6 and IC 14). Moreover, our findings indicate that GMC alterations in distinct subsystems can be differentiated in terms of the Dark Triad subscales.

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Part I: Theory

Personality Psychology and Personality Neuroscience

Personality neuroscience investigates the neural origin of affective modalities such as motivation, emotion, and individual differences (Whittle et al., 2006). Personality is associated with stability and consistency. In other words, personality refers to the continuity and reliability of individual variations in motivational, cognitive, and emotional elements of the mind, which contributes to similar behavioural patterns (Panksepp, 1998). While consistency is emphasized in personality, individuals do not behave consistently across environments, known as the personality paradox (Montag & Panksepp, 2017). Mischel (2004) proposes if-then functions to solve the paradox related to the definition of personality. By understanding the situational features that are essential elements determining an individual's behavioural consistency, if-then functions solve whether an individual does not behave in the same way in different situations. Personality psychology is a branch of psychology that studies the impact of personality characteristics on people's actions in diverse circumstances. In other words, personality psychology employs the trait approach, and the trait theory argues that characteristics or dispositions are parts of human personalities and that varying actions of the same individuals over time and under different circumstances are the results of the combinations of traits. Personality traits are specific patterns of attitudes, emotions, and feelings that appear consistent over time and circumstances (Allport, 1961). Although people's behaviour varies between circumstances, they behave consistently in many parts of daily life, such as when following routines, which provides a basis for the predictability. Individuals also possess traits, which are consistent dispositions that have a significant impact on a variety of activities over time and in different contexts (Ozer & Benet-Martinez, 2006), such as relationship fulfilment (Malouff et al., 2010), academic performance (Poropat, 2009), and, most particularly personality disorders (Ozer & Benet-Martinez, 2006; Samuel & Widiger, 2008). Two key hypotheses outline the trait approach in personality psychology. The first fundamental concept is that an individual's personality traits directly impact their behaviors (Matthews & Deary, 2002). Another way of describing it is that there is a causal link between the combination of traits that make up an individual's personality and the behavioral outcomes that result from that combination of traits (Brody, 1994). The fresh angle about traits states that different systems are engaged in the causal interaction between traits and behavioral consequences instead of the traditional perspective (Matthews, 2017). The causal relationship between characteristics and behaviors is mediated by distinct processes such as cognitive skills and self-awareness (Matthews, 2017). Furthermore, Fajkowska and Kreitler (2018) claim that the causality between behavior and trait is bidirectional; bottom-up causation implies that characteristics can be the causes of behaviors, while top-down causation implies that behaviors can be the causes of the traits that individuals possess. The second fundamental hypothesis is that personality traits are stable over time and across settings (Matthews & Deary, 2002). The second fundamental hypothesis is supported by substantial evidence in the literature (McCrae & Costa, 2008; Roberts & Wood, 2006), but there is also evidence that personality traits are not as consistent as the trait approach's conventional viewpoints claim and that individuals' personality characteristics change over time (Caspi et al. 2005; Ferguson, 2010).

Self-reports are prevalent tools in the social sciences, without the exception of personality science (Schwarz, 1999). Only 2% of the findings in the Journal of Research in Personality in 2003 did not use self-report measures as the primary tool (Vazire, 2006). Understandably, the immediate instinct would be to inquire about the individual's personality qualities, assuming that the subject of these characteristics will provide detailed and accurate information. Furthermore, self-reporting is a straightforward way to investigate personality traits, making it much easier to interpret (Kline, 1993). However, numerous studies need to be conducted to investigate and evaluate the inventories' validity and reliability, which can take substantial time and effort (John & Benet-Martinez, 2000). Self-reports are also inexpensive and easy to collect, making them suitable for research with many participants (Kline, 1993). For scientists who want to study with many participants to improve their studies' prediction power, utility is essential (Westen & Rosenthal, 2005). Because the practical aspect of self-reports is the primary incentive of adopting self-reports as a primary measurement in the social sciences, but certain disadvantages must be addressed. To begin with, participants may perceive a question differently than the questioner intended due to the structure of the questions in the self-reports (Schwarz, 1999). Second, self-reports are influenced by response bias, which is defined as the tendency to respond to questions in a systematic manner without regard for the actual content of the scale or what the question is meant to assess (Paulhus 1991), such as extreme responding, which means that participants tend to rate items on scales with extreme ratings (Paulhus Vazire, 2007). For example, individuals prefer to answer inquiries by considering how socially acceptable or positive the response they want to provide is rather than by relying on their feelings or actions (Paulhus, 1991). Another reason for the social desirability bias is that individuals respond favourably or socially desirable because their opinions of themselves can be incorrect (John & Robins, 1994). To put it in other words, we have a distorted self-perception of ourselves, and we tend to enhance our egos by generating an overly optimistic picture of ourselves. As demonstrated by numerous studies in the literature, the limitations of self-reports indicate that there are several risks to the accuracy of self-reports, and there are strategies to improve the reliability of the answers provided by participants. However, these techniques do not address a lack of self-awareness, directly decreasing the relevance of data obtained through self-report. Accepting self-reports as the primary way to assess a personality trait is a clear threat to the significance of an empirical analysis, and alternative methodologies should be combined with the self-report to address the drawbacks while retaining the benefits of self-reports (Kagan, 1988). Recognizing the validity of the instrument used to assess the personality traits, as well as any assumptions that may have a negative influence on the validity, is a critical step in choosing which methods should be paired.

Personality research has emphasized the biological and neuronal perspective due to evidence related to personality traits' biochemical and neurological origins (Widiger, 2013). The temperaments of various animal species can be explained using personality traits similar to those used to define human temperaments (Gosling & Vazire, 2002). Hyenas, for example, were used in research focusing on neuroticism to better understand human mood disorders. They observed that female hyenas are more neurotic than male hyenas, a finding that has been confirmed in human beings (Gosling, 1998). Personality is a result of connections between the brain and the environment, according to several studies. Various approaches are used to investigate the link between personality characteristics and a particular brain system (Birn et al., 2014). The literature shows that by integrating personality psychology with neuroscience, concerns connected to the techniques employed in personality psychology may be addressed (Fung et al., 2014). As a result, the emphasis in psychology on the neurological foundation of human behavior is not concurrent, which contributes to emerging fields such as personality neuroscience, which focuses on understanding individual differences in the brain and associated functions (DeYoung & Gray, 2009).

The advancement of non-invasive imaging techniques has enabled researchers to investigate the neurological basis of human differences. For example, magnetic resonance imaging (MRI) is a non-invasive method that generates 3D brain pictures based on the characteristics of the brain's many components. The most common MRI techniques are diffusion MRI (DWI), functional MRI (fMRI), and structural MRI (sMRI). Voxel-based morphometry (VBM) is used in several sMRI research in personality neuroscience (Blankstein et al., 2009, Ashburner & Friston, 2000 & Xu et al., 2009). VBM is a practical and helpful approach for comparing gray matter concentrations in different brain areas (Ashburner & Friston, 2000). Although VBM provides a method for understanding variations in gray matter concentrations, the outcomes of VBM research are very variable and inconsistent. For example, the research discovered a positive and negative association between the agreeableness trait and the volume of the posterior cingulate cortex, demonstrating the VBM studies' conflicting findings (Coutinho et al., 2013; DeYoung et al., 2010). Source-based morphometry (SBM) is a multivariate variant of VBM used to compare white and gray matter differences between patients and healthy controls (Xu et al., 2009). Furthermore, surface-based morphometry (SBM) is a promising method for studying personality and associated structural features in the brain since it allows us to examine various structural properties of the brain such as cortical volume, folding, and cortical thickness (Rauch et al., 2005; Riccelli et al., 2017; Wright et al., 2006). Structural MRI studies have the ability to overcome limited sample sizes because structural images produced by MRI studies in general and researchers may use data that is freely available to the public as a result of open science practices (Miller et al., 2016; Van Essen et al., 2013).

In conclusion, personality neuroscience is a developing field that blends psychological and neuroscience findings and methodologies. Thus, the present understanding of the human differences in personality traits corresponds to psychology's theoretical underpinnings and neuroscience's advanced methodologies. The intersection of neuroscience and psychology leads to scientific investigations, and the quantity and quality of these investigations are increasing on a daily basis.

Dark Side of Personality: The Dark Triad

In their original paper, Paulhus and Williams (2002) attempted to explain the literature on aversive personalities within the typical spectrum of behavior, and three elements remained: Machiavellianism, subclinical narcissism, and subclinical psychopathy (see Table 1). While all three had significant previous literature, they all suffered from 'construct creep,' or the tendency for academics to keep accumulating research associated with the specific construct (Jones & Paulhus, 2011). The ambiguity between the Dark Triad's components was to be expected, given that the three components have a theoretical resemblance and comparable measurements associated with each other. Paulhus and Williams (2002) investigated to assess the degree of distinctiveness of the components of the Dark Triad, both theoretically and empirically, in order to distinguish the three members of the Dark Triad, which are Machiavellianism, subclinical narcissism, and subclinical psychopathy (Paulhus & Williams, 2002). Individuals in the general community who exhibit specific characteristics comparable to those seen in the psychiatric (institutionalized or imprisoned) population are referred to be subclinical. The line between "normal" and "abnormal" personality has always been difficult to distinguish (Allport, 1937). In the research on personality disorders, the words clinical and subclinical are commonly used interchangeably (Lebreton, Binning & Adorno, 2006). In this dissertation, terminology will be seen in the following ways: Clinical samples are individuals who are under psychiatric or criminal monitoring; subclinical samples are consistent fractions of broader population samples. There is a frequent misconception that subclinical refers to a lesser version of a condition; however, this is not always the case because subclinical samples must have a larger spectrum and contain severe cases (Furnham, Richards & Paulhus, 2013).

Even though these three personality traits are correlated, the correlation between them is modest, indicating that each of these three traits represents a separate element of the dark personality concept (Jonason, Koenig & Tost, 2010; Paulhus & Williams, 2002), but they all share at least two key characteristics: manipulation (Jonason et al., 2009) and a lack of empathy towards others (Jones & Paulhus, 2011). Callous exploitation (Jones & Figueredo, 2013) or a lack of honesty (Book, Visser, and Volk, 2015) have also been proposed as potential characteristics. Dark Triad features may also be essential and beneficial in understanding the development of undesired and malicious tendencies, which are frequently evident in children and adults who engage in criminal and antisocial activities (Lyons & Jonason, 2015). Individuals that score high on the Dark Triad likely are to be more prejudiced and racist (Hodson, Hogg, and MacInnis, 2009). Moreover, individuals who score high on all three Dark Triadtraits have less empathy for others (Wai and Tiliopoulos, 2012).

The Machiavellianism-IV scale (Christie and Geis, 1970), the Narcissistic Personality Inventory (Raskin and Hall, 1979; Raskin and Terry, 1988), and the Self-Report Psychopathy Scale were used quite often to assess Dark Triad traits (see Table 1; Paulhus et al., 2016). The Dirty Dozen (DD; Jonason and Webster, 2010) and the more current one which is Short Dark Triad (SD3) are both shorter combined versions of all these assessments (Jones and Paulhus, 2014). These brief measures make it easier to investigate each characteristic simultaneously while also minimizing the time it takes to complete the assessment. In behavioral science, there is undoubtedly a strong need for these brief yet reliable questionnaires. The SD3 scale was created to assess the dark triad, as Jones and Paulhus (2011) defined, by focusing on the definitions and aspects for every three traits (Paulhus and Jones, 2015). The SD3 scale was created to measure the Dark Triad as a combined version of individual components (Paulhus and Jones 2015). The three 9-items subscales of Machiavellianism, Narcissism, and Psychopathy that form the SD3 were created using exploratory factor analyses of a more extensive data set on multiple big population datasets. The three-factor approach received additional validation from the exploratory, confirmatory factor analysis (Jones and Paulhus, 2014). In cross-validation sampling, the SD3 subscales obtained Cronbach alpha values varying from .70 to. 80, and 2-week test-retest reliability coefficients generally range from .77 to.84 (Paulhus and Jones, 2015). The SD3 subscales had inter-correlations ranging from .22 to .55 (Jones and Paulhus, 2014). Moreover, there has been evidence of convergent validity and discriminant validity with the conventional Dark Triadscales (Jones and Paulhus, 2014; Lee et al., 2013).

Table 1

Characteristics of the Dark Triad traits and a Summary of the Frequently Adopted Measurements for Examining These Concepts

Dark triad trait	Key feature(s)	Most important scale	Alternative scales
Narcissism	The pursuit of gratification from vanity or egotistic admiration of one's own attributes	Narcissistic Personality Inventory (NPI): 40-item scale representing seven dimensions: authority, self-sufficiency, superiority, exhibitionism, exploitativeness, vanity, and entitlement	Dirty Dozen (DD): Four items relating to exhibitionism (2), superiority (1), and entitlement (1) Short Dark Triad (SD3): Nine items representing superiority (4), exhibitionism (2), entitlement (2), and authority (1)
Machiavellianism	A duplicitous interpersonal style, a cynical disregard for morality, and a focus on self-interest and personal gain	MACH–IV: 20-item inventory tapping three categories: manipulative tactics, cynical view of human nature, and disregard for conventional morality	DD: Four items that have to do with interpersonal tactics (3) and disregard for conventional morality (1) SD3: Nine items concerned with interpersonal tactics (7) and disregard for conventional morality (2)
Psychopathy	A personality trait characterized by enduring antisocial behavior, diminished empathy and remorse, and disinhibited or bold behavior	Self-Report Psychopathy Scale (SRP–III): 64-item questionnaire consisting of four factors: interpersonal manipulation, callous affect, erratic lifestyle, and criminal tendencies	DD: Four items tapping callous affect (4) SD3: Nine items representing interpersonal manipulation (1), callous affect (2), erratic lifestyle (3), and criminal tendencies (3)

Note. From "The malevolent side of human nature: A meta-analysis and critical review of the literature on the dark triad (narcissism, Machiavellianism, and psychopathy)." by Muris, P., Merckelbach, H., Otgaar, H., & Meijer, E., 2017. *Perspectives on Psychological Science, 12(2).* (https://doi.org/10.1177/1745691616666070). 2021 American Psychological Association.

Machiavellianism

Niccolo Machiavelli (1469-1527) was a Florentine politician who observed the rise and decline of their leaders by attending European courts. He wrote The Prince (Machiavelli, 1513/1966), a book of suggestions about gaining and maintaining authority that is entirely founded on pragmatism and lacks the moral standards of honesty, respect, and dignity. His name has given rise to the concept of a social interaction technique in which all others are perceived mainly as a means of control and achieving the desired goal. Christie and Geis (1968, 1970) were the first to investigate Machiavellian tendencies such as cynicism, a lack of social empathy, and a complete disregard for traditional morals. Machiavellians seek to influence, status, or material resources through several collectively insensitive or immoral actions. Machiavellians distrust others, seeing them as risks to their position and financial benefits (Dahling et al., 2009). According to the studies in the literature, Machiavellians are competitive and pursue external targets (e.g., prestige and economic power), lacks socio-emotional comprehension, have less empathy, and have lower emotional intelligence than non-Machiavellians (Barlow et al., 2010; Ali et al., 2009). They have a short-term interpersonal relationships preference (Chabrol et al., 2009), frequently defect from trusted exchange relationships, they "strike first" without prior provocation, do not engage in much contextual performance (Jones & Paulhus, 2009; Christie & Geis, 1970).

To put it simply, Machiavellians exhibit a social interaction that includes exploiting others for short-term personal advantage, very much against the other individuals` gains (Wilson et al., 1996), actively participate in manipulation (Austin et al., 2007), and many can convince themselves with managers notwithstanding their poor work quality (Struthers, Weiner, & Allred, 1998). Machiavellians` chronic involvement in deceptive strategizing is assumed to begin in early childhood

(McIlwain, 2003; Repacholi et al., 2003); interacting with the social world determines the way Machiavellian brains evolves according to neuroplasticity concepts. Neuroplasticity indicates alterations in the neural structure of the cortex caused by interactions acquired in the social world; those adjustments subsequently influence future interactions with the world. Neuroplasticity is most pronounced at an early age, but it persists throughout adulthood, as shown by an individual's ability to heal after damage (Buonomano & Merzenich, 1998). Significant changes in cerebral cortex thickness and folding were already found in individuals with chronic and psychiatric conditions such as schizophrenia (Leung et al., 2009), autism (Boddaert et al., 2004), bipolar disorders (Lyoo et al., 2004), Down Syndrome (White et al., 2003). Prolonged involvement with the environment has also been found to cause local adjustments in brain activity as well as numerous, separable adjustments in the brain, such as changes in dendritic length, fluctuates in spine density, synaptic development enhanced glial activation, and modified metabolic rate (Kolb & Whishaw, 1998) which is evidenced at the structural level; for instance, structural organization of the brain vary among musicians and non-musicians (Gaser & Schlaug, 2003), jugglers and non-jugglers (Draganski et al., 2004).

The above results imply that adjustments in a gray matter and white matter can be caused by constantly engaging with the social world. The basal ganglia (the rewarding center) left prefrontal cortex (used in strategy to overpower others and control of negative emotions), bilaterally in the insula (involved in the feeling of disgust as well as the desire to overcome unpleasant emotional reactions), and in the right hippocampus and left Parahippocampal gyrus both showed positively significant variations for high versus low Machiavellianism (responsible from such as processing contextual cues and learning) (Verbeke et al. 2011). The areas mentioned above are linked to Machiavellian impulses, including deceitful political maneuvering (e.g., to do whatever it intends to reach anything they desire without being detected so that their social position is indeed not adversely affected).

Narcissism

The concept of narcissism was shaped by the ancient Greek myth of Narcissus, a highly narcissistic figure who refuses the love of another as undesirable and falls in love with his reflection. The myth of the Narcissus has indeed been presented in different variations by ancient literature, and each lead to a tragedy. Narcissus' tragic ends offer a clear template for psychological concepts about the risks and effects of a dysfunctional fixation with the personal image (Grenyer, 2013). Wälder (1925) was the first to formulate the idea of a narcissistic personality trait. Individuals with narcissistic traits are patronizing, feeling superiority to many others, and fixated about superiority, and displaying a pronounced lack of empathy, which is perhaps more visible in their sexual behavior, founded solely on physical gratification rather than mixed with emotional affection (Wälder, 1925). Moreover, individuals with narcissistic traits were extremely self-reliant, sociable, not quickly frightened, violent, and incapable of loving or committing in solid interpersonal relationships (Freud, 1957). Horney (1939) expanded on the theory that narcissism was a personality trait, proposing that narcissists did not experience adverse outcomes from excessive self-love but were unwilling to love others, even themselves. Winnicott (1965), in harmony with Horney, differentiated between a genuine and false concept of self and suggested that narcissistic people defend themselves by identifying with a grandiloquent false sense of self. Reich (1960) suggested that narcissistic people have a failure to control their self-esteem because of frequent prior negative experiences, reflecting on the concept of narcissism as a shield against being vulnerable or powerless. Thus, they create a false understanding of self which is extremely self-protective and grandiose in which the self is not fragile but instead protected, powerful, and more significant than others.

Nemiah (1961) introduced the concept of narcissistic personality disorder (NPD) and stated explicitly that narcissism is not just a personality trait and sometimes a personality disorder. Eventually, Kohut (1968) and Kernberg (1970) enlarged the concept of NPD by giving detailed descriptions of the clinical narcissism, proposed a classification focused on easily identifiable behavioral patterns, and differentiated between subclinical and clinical narcissism. While Kohut and Kernberg differed on the underlying cause and intervention regarding narcissistic personality, they agreed on most of its expression, especially in the subclinical spectrum (Kenneth et al., 2012). In neither the first edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM) or DSM-II, NPD was an actual diagnosis (Kenneth et al., 2012). The terms narcissism and NPD are not synonymous, and the publishing of the DSM-III (American Psychiatric Association [APA], 1980), which transitioned psychiatric definitions into a practical term, eventually providing measurable parameters, was a critical construct transition (Rhodewalt & Peterson, 2009). The latest version of the DSM defines narcissism as a complex construct due to its inconsistent definitions in different fields (i.e., clinical psychology, psychiatry, personality psychology). Narcissism is a rather complicated concept because of contradictory concepts in several disciplines such as psychiatry, clinical psychology, and personality. In the DSM's many versions, it is hard to distinguish between subclinical and clinical narcissism or NPD. Narcissism has been most widely studied in subclinical populations using the Narcissistic Personality Inventory (NPI; Raskin & Hall, 1979; Raskin & Terry, 1988). Thanks to Raskin and Halls' (1979) effort to describe a subclinical variant of the DSM-defined personality disorder resulted in the concept of subclinical narcissism. Grandiosity, entitlement, supremacy, and superiority were all aspects of the psychiatric condition that remained. An extensive scientific literature supports the effective transition from therapeutic to subclinical constructs (Morf & Rhodewalt, 2001).

Neuroscience has come a very long way in understanding the brain processes that enable us to put ourselves in other people's shoes which is also named as empathy. A recent study found neural and functional differences in empathy-related brain areas in individuals with strong narcissistic personality traits. Findings showed that reduced activity in the right anterior insula was correlated with increased levels of narcissism in an empathy condition in what could be the earliest functional MRI (fMRI) report on subclinical narcissism (Fan et al., 2011). The anterior insula, the left inferior frontal cortex (including the mirror neurons), as well as other areas such as the premotor cortex and the dorsolateral prefrontal cortex (DLPFC; Decety & Lamm, 2006; Singer & Lamm, 2009) have all been established as critical components of the neural network associated with empathy. For instance, individuals with lesions induced by extracting brain tumors in the anterior insular cortex (AIC) had deficiencies in overt and subtle empathetic pain processing (Gu et al., 2013). Moreover, this research provides evidence that the empathy deficiencies in individuals with AIC injury are remarkably close to the empathy deficiencies shown in a variety of psychiatric conditions, namely borderline personality disorder, NPD, and others, implying that all those psychiatric disorders which shared a common neurological substrate (Di Sarno et al., 2018). The anterior insula has been the most prominent of these empathy-related areas since it is involved not only in empathy with one another but also in reflecting on oneself (Enzi et al., 2009; Modinos et al., 2009). According to Fan et al. (2011), subjects with elevated narcissism have altered activation in the anterior insula instead of those with low narcissism because they have a high self-focus. Higher-order perceptual and emotional functions have a neuronal basis within the frontal lobes. Emotion regulation, behavioral avoidance, and emotional empathy are all frontal cortex functions (Morelli et al. 2014, Ochsner & Gross 2007, Shamay-Tsoory & Aharon-Peretz, 2007). Frontal areas and their connectivity with the related areas play an essential part in narcissism and personality disorders. Narcissists are not only suffering from a lack of empathy, but they often struggle with emotion modulation (Altmann 2017, Di Pierro et al. 2017). An investigation of 17 NPD patients using voxel-based morphometry found decreased grey matter volume in frontal-paralimbic brain regions (Schulze et al., 2013). These results are compatible with previous research on the neuronal basis of narcissism in nonclinical populations.

Psychopathy

Psychopathy is a severe personality disorder marked by egocentrism, insensitivity, antisocial behaviour and a pathological impairment in empathy, all of which make it challenging for a person to develop warm, stable interpersonal relationships with anyone (Hare, 2003). The Mask of Sanity is considered as a guide to characterizing the stereotypical psychopath, based on numerous psychiatric findings of male patients classified as "psychopathic" (Cleckley, 1988). Moreover, Cleckley (1988) described 16 psychopathic traits: superficial charisma, lack of delusions and anxiety, unpredictability, dishonesty, lack of guilt, antisocial behavior, poor reasoning, pathologic self-centeredness, and incapacity for love, affect and empathy, severe impairments in sensitivity and interpersonal interactions, illogical and unapproachable behavior. This dissertation is mainly concerned with subclinical version of psychopathy, also known as successful psychopathy. Although the literature on subclinical psychopathy is consistently growing with the increasing curiosity in the Dark Triad, there is little consensus on what subclinical psychopathy means. According to Hall and Benning (2006), a subclinical psychopath is a person that possesses many of the psychopathic traits but may not engage in extreme antisocial behavior and is consequently seldom incarcerated or institutionalized. In other words, the subclinical psychopath engages in activities that violate social standards but are not technically criminal, such as gaining personal or career achievement at the detriment of others, which is why the word "successful psychopathy" is often used synonymously (Hall & Benning, 2006). Nevertheless, this definition is more in line with Machiavellianism, as psychopaths are famous for failing to achieve long-term personal or career goals (Furnham et al., 2013). There are two significant factors to draw a clear line between clinical and subclinical psychopathy. To begin with, subclinical psychopaths are much less antisocial than clinical psychopaths; however, it does not suggest they are almost always nonviolent. The second factor is that the clinical psychopath is determined not by the person's present positions but rather by their criminal records and other factors. As a result, a psychopath who has been accused of many offenses but is still living in society is should not defined as a successful psychopath (Gao & Raine, 2010). Glenn and Raine (2014) include four distinct base classifiers to differentiate clinical and subclinical or successful psychopathy in a more recent article; people with a high psychopathy score but have not ever been accused of a criminal offense, not imprisoned, maintain a high socioeconomic standing, and the serial murderers that have escaped justice for an extended period. There is much theoretical distinction between these classifiers, which could trigger issues. Since only a small percentage of pathological psychopaths are incarcerated, the difference between the clinical and subclinical psychopaths becomes a matter of time. Furthermore, a comparison between the clinical and subclinical psychopathy must be cross-culturally transferrable, and therefore, it cannot depend solely on imprisonment history since individuals are imprisoned for various reasons in many countries. Assuming that the psychopathy classification is categorical, further analytical analysis and experimental work are required to create unarbitrary comparisons between the clinical and subclinical psychopathy.

The three key theoretical frameworks have been defined by Hall and Benning (2006) to solve the problematic classification between subclinical and clinical psychopathy. According to the first theoretical framework, subclinical psychopathy exhibits similar aetiological distinctions as clinical psychopathy, however often to a lesser extent (Hall & Benning, 2006). Clinical and subclinical psychopaths vary only in extent, not nature (Gustafson, & Ritzer, 1995). Their findings identified the subclinical psychopaths as someone who is exploiter, lacks empathy, violates societal standards, and engages in extremely selfish actions, even though their actions are not legally criminal. The second theoretical framework suggests that clinical and subclinical psychopathy have a similar aetiology and a fundamental pathology of a similar extent. Individuals may possess similar traits as psychopaths, except for having a sufficient degree of social interactions throughout their childhood, which has prevented them from engaging in antisocial actions (Lykken, 1995). In other words, the theoretical perspective claims that if a person has compensating variables such as a healthy childhood, high social class, and so on, antisocial actions can be minimized (Hall & Benning, 2006). The final theoretical framework, which is the dual-process, or dual-deficit model of psychopathy (Fowles & Dindo, 2006), argues that the interpersonal–affective aspects of psychopathy are thought to be aetiologically distinguished from the antisocial behavior element (Fowles & Dindo, 2006). Considering that these dual trait parameters are assumed to represent different aetiologies, certain people can show an increase in only one (Hall & Benning, 2006). As a result, the subclinical psychopathy can have increased degrees of interpersonal characteristics but average degrees of antisocial traits. This framework is based on the two-factor model of psychopathy, which explains different behaviors such as high scores on the interpersonal aspect while low scores on the affective aspect. In conclusion, the first and second frameworks propose that psychopathy as a construct belongs to a spectrum, while the third framework claims that there is a clear distinction in aetiologies between clinical and subclinical psychopathy.

Subclinical psychopathy research presents several challenges. First of all, antisocial behavior has been described by DSM-III (American Psychiatric Association, 1980) and DSM-IV (American Psychiatric Association, 1994) , which has caused an inadequate representation of other attitudes and characteristics (Lilienfeld, 1998; Messick, 1995). Secondly, determining subclinical psychopathy has proved to be challenging. Finally, psychopathy is not as systematically screened in non-clinical settings as they are in clinical settings (Hall & Benning, 2006). As a result of these issues, innovative measures such as the Psychopathic Personality Inventory (PPI; Lilienfeld & Andrews, 1996) were developed to obtain comparable results from the broader population.

Since the case of Phineas Gage, neuroscientists have been investigating brain anomalies in psychopaths. Gage was seriously wounded by an iron bar that reached his prefrontal cortex (PFC), primarily the orbitofrontal cortex (OFC), leading to significant personality alterations (O'Driscoll & Leach, 1998). Gage has been classified with latent sociopathy or pseudo psychopathy, characterized by impulsive and antisocial behavior. According to Blair (2003), pseudo-psychopaths do not engage in the interpersonal aggression that psychopaths do, which is consistent with the case of Gage. Broomhall (2005) found that pseudo-psychopaths appear to rank highly on Psychopathy Checklist (PCL) factor 2 like subclinical psychopaths, while clinical psychopaths score highly on both measures, which explains the case of Phineas Gage. There has been a rise in fMRI research in psychopathy in recent decades, with meta-analytic results highlighting decreases in the right orbitofrontal cortex, right anterior cingulate cortex, and left dorsolateral prefrontal cortex (Yang & Raine, 2009). Ermer et al. (2013) reported that younger samples with psychopathic tendencies have structural abnormalities comparable to those reported in the general population. Psychopathy scores measured by Psychopathy Checklist Youth Version was shown to be negatively associated with gray matter volume in paralimbic areas, and multiple regression analysis revealed that the gray matter volume of different areas of the brain could determine psychopathy score (Ermer et al., 2013) The orbitofrontal cortex is the most frequently investigated (Anderson & Kiehl, 2012), and major structural alterations between clinical and subclinical psychopaths regarding the medial frontal cortex (MFC) and orbitofrontal cortex (OFC) was described by Yang et al. (2010). Clinical psychopaths demonstrated structural deficiencies in the MFC, OFC, and amygdala, but not subclinical psychopaths. Moreover, subclinical psychopaths had greater grey matter volume in the left middle frontal cortex and superior frontal cortex than the control group, which was unexpected (Yang et al., 2010). The structural abnormalities identified in clinical psychopaths but not in subclinical psychopaths provide strong evidence that there is a substantial distinction between both groups. Alterations related to functional and structural properties of the amygdala in clinical psychopaths have been reported (Dolan & Fullam, 2009; Pardini et al., 2014), but not in subclinical psychopaths (Yang et al., 2010). A similar result remains for the prefrontal cortex, where clinical psychopaths have lower gray matter volume but not subclinical psychopaths (Yang, et al., 2005; Yang et al., 2009). Raine et al. (2004) also identified the same pattern, which is a high anterior hippocampal volume asymmetry (right > left) compared either to control or subclinical psychopaths. Since either clinical or subclinical psychopaths lack affective empathy, the associated brain regions should display alterations. Nevertheless, disruption to the amygdala may be separable compared to controls but not to subclinical psychopaths. Yang et al. (2010) examined this issue. They predicted that clinical psychopaths, but again not subclinical psychopaths, will have substantial volume decreases in the OFC, DLPFC, and amygdala as opposed to controls. The researchers supported their assumption by identifying structural deficiencies in both the prefrontal cortex and the amygdala in clinical psychopaths, not in subclinical psychopaths. Moreover, clinical psychopaths have a 26% decrease in left amygdala volume and a 20% decrease in right amygdala volume than the control group. The identified volume decline of subclinical psychopaths was lower, with 9.3 percent in the left and 12.7 percent in the right amygdala.

Age and Gender Trends in the Dark Triad

Men are much more likely than females to engage in transgressive behaviors, which is demonstrated by the research findings in externalizing psychopathology. Males demonstrate more conduct problems, delinquent behavior, and aggression than females in early life (Moffitt et al., 2001). This gender gap persists in later life when males are more commonly classified with antisocial personality disorder (Cale & Lilienfeld, 2002) and actively participate in criminal activity (Rowe et al., 1995) than females.

Gender variations in each component of the Dark Triad traits have been studied independently. Grijalva et al. (2015) synthesized previous research findings on Narcissism by conducting a meta-analysis. Their findings revealed that males were more narcissistic than females but with a low to moderate effect size. The difference between the males and females in different aspects of Narcissism was represented mainly through Narcissism's different characteristics, such as exploitativeness, arrogance, and egocentrism. In the existing literature of the gender differences in psychopathy, various descriptive reviews have been conducted, all of which showed evidence that the characteristics of psychopathy are more significantly prevalent in males than in women, including criminal, clinical, and sub-clinical populations (Cale & Lilienfeld, 2002; Nicholls et al., 2005). Although empirical research on gender differences in Machiavellianism is limited, existing literature suggests that Machiavellianism is more prevalent in males (Krampen et al., 1990).

We found no research addressing age patterns in Dark Triad from adolescence to adulthood, indicating that research explicitly focused on age trends in Dark Triad is limited. Nevertheless, there are significant external indicators that there are age-related patterns in the Dark Triad. For instance, scales used to measure the Dark Triads are connected to the Big Five (Vize et al., 2018) and HEXACO measurements (Muris et al., 2017). These connections show a reduction in maturity-related traits such as honesty-humility, agreeableness, and conscientiousness in adolescent years and a rise in those characteristics in the preadolescence years (Ashton and Lee, 2016, Denissen et al., 2013, Roberts et al., 2006, Soto et al., 2011). There are negative associations between honesty-humility, agreeableness, conscientiousness, and Dark Triad traits (Muris et al., 2017, Vize et al., 2018). Low honesty-humility, low agreeableness, and low conscientiousness have been regarded as a predisposition to deliberately exploit other individuals (Ashton & Lee, 2007), which overlaps with the Dark Triad traits. As a result of assuming age correlations of measures in main personality measures, Dark Triad traits will positively correlate with age in teenage years but negatively correlated with age in adulthood. According to Spurk and Hirschi (2018), there are reduced Dark Triad traits in senior employees between the ages of 50–59 than junior employees between the ages of 25–34. Moreover, other empirical evidence supports that there is a negative correlation between the Dark Triad traits and age in the adulthood years (Barelds, 2016, Craker and March, 2016).

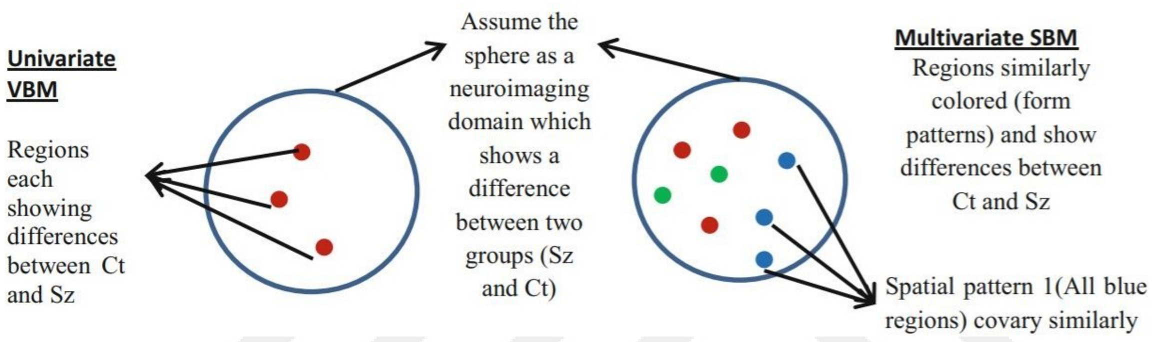
In conclusion, studies have shown that the Dark Triad traits are more prevalent in males than females. Although the Dark Triad traits are investigated individually to understand the gender differences, there is a need to explain the gender differences of the Dark Triad as a combination of three traits. Moreover, the studies found that that there are positive relationships between the age and the Dark Triad traits throughout early adolescence, and then the relationship between the age and Dark triad traits becomes negatively associated during mid adolescent years.

Source Based Morphometry

Source-based morphometry (SBM, Xu et al., 2009) is a data-driven approach that utilizes independent component analysis (ICA, McKeown, & Sejnowski, 1998) to create a multivariate alternative of voxel-based morphometry (VBM) by integrating signals across various voxels and examines the individual covariation of these trends rather than evaluating each voxel independently. As a result, the spatial connection within distinct brain areas is preserved, represented graphically in Figure 1 (Gupta et al., 2018, p. 106; Sui et al., 2012; Pearlson et al., 2015).

Figure 1

Comparative representation of univariate and multivariate analyses in a singular neuroimaging modality

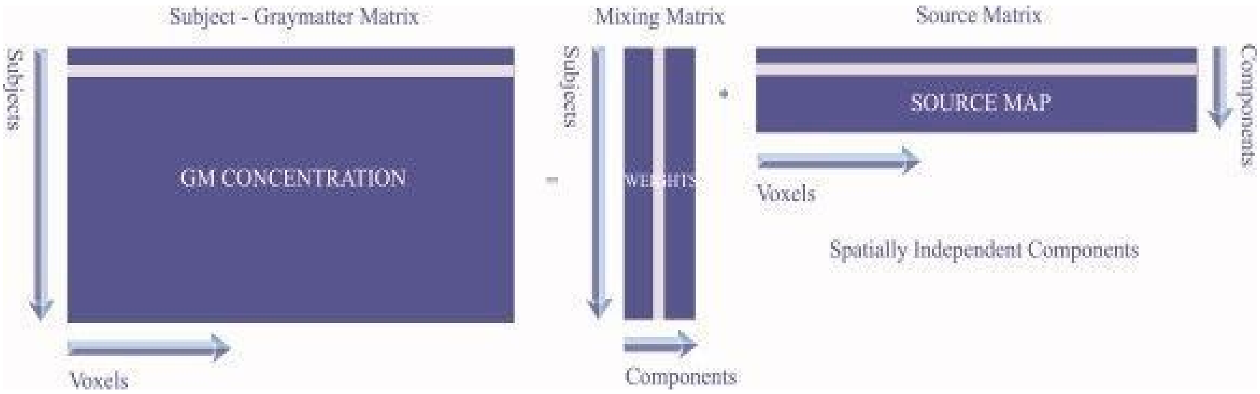


Note. Modified from "Source-Based Morphometry: Data-Driven Multivariate Analysis of Structural Brain Imaging Data," by Gupta, C. N., Turner, J. A., & Calhoun, V. D., 2018. *Neuromethods*, *136*, p. 106 (https://doi.org/10.1007/978-1-4939-7647-8_7). 2021 Elsevier B.V

Moreover, SBM operates as a spatial filter and does not need a pre-decision of brain areas to evaluate. SBM starts with the identical pre-processing steps as VBM (normalization, segmentation, and smoothing). ICA identifies inherently clustering, independent sources. Each gray matter pre-processed image is transformed as a single vector using ICA, and then all vectors are arranged into a single participant-by-gray matter output matrix. As shown in Figure 2 (Xu et al., 2009, p. 715), this matrix is deconstructed into the mixing matrix, which expresses the interaction between participants and components.

Figure 2

ICA model in which the subject-by-gray matter matrix was decomposed into mixing matrix and source matrix.

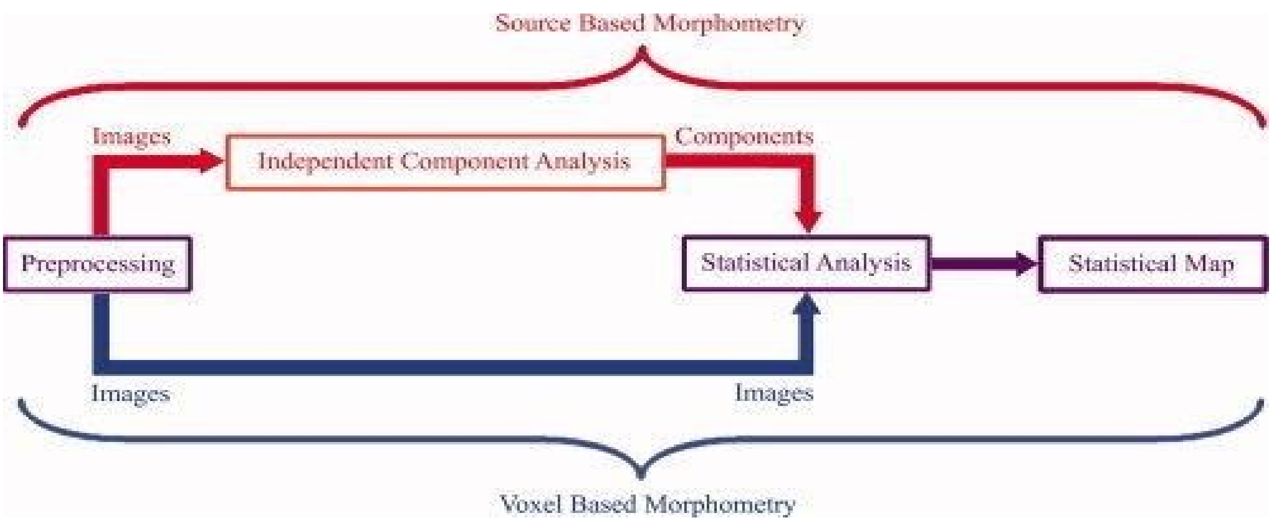


Note. Modified from "Source-based morphometry: the use of independent component analysis to identify gray matter differences with application to schizophrenia" by Xu L, Groth KM, Pearlson G, Schretlen DJ, & Calhoun VD, 2009. *Human brain mapping, 30*(3), p. 715. (https://doi.org/10.1002/hbm.20540). 2008 Wiley-Liss, Inc.

SBM detects "source networks," which are clusters of spatially different areas with similar covariation among participants, giving information on the localization of gray matter alterations as well as their variation among individuals, using the ICA. As shown in Figure 3 (Xu et al., 2009, p. 713), the fundamental distinction between SBM and VBM is ICA application.

Figure 3

The approach difference between source-based morphometry and voxel-based morphometry.



Note. Modified from "Source-based morphometry: the use of independent component analysis to identify gray matter differences with application to schizophrenia" by Xu L, Groth KM, Pearlson G, Schretlen DJ, & Calhoun VD, 2009. *Human brain mapping, 30*(3), p. 713. (https://doi.org/10.1002/hbm.20540). 2008 Wiley-Liss, Inc.

ICA is a type of blind source segregation (BSS) approach utilized to extract fundamental source signals from linearly mixed data without previous knowledge of the source signals (Hyvärinen, & Oja,2000; Lee, 1998). ICA is a subtype of BSS in which the fundamental sources are assumed to be isolated or independent. Equation (1) (Gupta, Turner, & Calhoun, 2018, p. 107) gives the instantaneous (linear) noise-free mixing model (Hyvärinen & Oja,2000; Lee, 1998) where X signifies linearly collected sources, S the core independent components, A the mixing matrix, and W the unmixing matrix (the reverse A). Every ICA algorithm's objective is to provide the matrix (W) as shown in Equation (1) (Gupta, Turner, & Calhoun, 2018, p. 107), which allows predicting the fundamental independent sources (S) up to a factor of scaling and permutations.

$$X = AS;\ \hat{S} = WX,\ \ W = \mathrm{inv}(A) \tag{1}$$

Note. Modified from "Source-Based Morphometry: Data-Driven Multivariate Analysis of Structural Brain Imaging Data," by Gupta, C. N., Turner, J. A., & Calhoun, V. D., 2018. *Neuromethods*, *136*, p. 107 (https://doi.org/10.1007/978-1-4939-7647-8_7). 2021 Elsevier B.V

VBM is a univariate technique, does not use any information about the interconnections between voxels and identifies only voxels for which a particular anticipated effect is evident. On the other hand, SBM is a data-driven multivariate technique that considers information across brain voxels and delivers spatially optimal independent sources concerning the localization of alterations (i.e., "networks"). SBM is beneficial to eliminate sources that display clear artefactual patterns in this manner, consisting of spatial filtering of the outputs, which VBM cannot accomplish. Furthermore, SBM has shown greater sensitivity and specificity compared to VBM (Xu et al., 2009), particularly when there are overlapped areas: SBM can identify a single voxel to different sources, providing more precise findings.

The application of SBM offers several significant benefits:

1. SBM enables noise reductions in the findings by spatially filtering artefactual sources.
2. Unlike VBM, SBM is a multivariate approach that considers voxel interrelationships rather than voxel by voxel comparative analysis. The mixing matrix properties are estimated using SBM, preserving the interrelationship of sources across participants, which can be investigated to discover sources that differ between groups in the study.
3. SBM can efficiently distinguish various sources, demonstrating how distinct brain areas may be classified within connected networks.

Moreover, VBM tends to be less sensitive, particularly for the overlapping areas, including some that exhibit a group difference and others that do not. However, SBM can identify a particular voxel to several sources, demonstrating improved gray matter localization. In conclusion, since SBM is a multivariate technique, SBM becomes a practical technique to investigate voxel interrelationships to identify clustered brain areas and identifying regions with common fundamental intercorrelations like gray matter across participants.

Table 2

Comparison between SBM and VBM

Source-based Morphometry	Voxel-based Morphometry
Multivariate Nature	Univariate Nature
Separates distinct naturally connected circuits by taking into consideration interrelationships between different voxels.	Inter-regional interactions are not detectable.
Because it can identify a single voxel to several sources, it has better sensitivity and accuracy.	Sensitivity is reduced, particularly in overlapping areas.
Artefactual sources are spatially filtered to reduce noise.	Misregistration and mismatches can potentially have a substantial impact on voxels outside the brain or in the incorrect areas.
Statistical analyses are conducted on a smaller number of sources reducing the number of comparisons.	There are too many comparisons because of the voxel-by-voxel statistical analysis.

Part II: Experimental Project

Introduction

The Assassination of Gianni Versace is an American crime show covering the homicide of fashion creator Gianni Versace by Andrew Cunanan, who have assassinated four other individuals without feelings of regret and guilt over three months mid-1997 (Pearson et al., 2018). Cunanan has been portrayed as superficial and charming. He displayed early behavioral issues because he began compulsively lying in his childhood years, which remained in adulthood. He was a master of deception and manipulation who walked freely through society thanks to his malevolent brilliance (Cipriano, 2019). The case of Andrew Cunanan can be explained by three distinct personality characteristics linked to norm-breaking and transgressive behavior: subclinical narcissism, Machiavellianism, and subclinical psychopathy. Paulhus and Williams (2002) coined the word "Dark Triad of Personality" to describe these characteristics, which are believed to play a central role in many norm-violating actions (Furnham et al., 2013).

The terms subclinical narcissism, Machiavellianism, and subclinical psychopathy each have their definitions and origins. In a nutshell, the construct of Machiavellianism is the manipulative personality (Paulhus & Williams, 2002). Since the 1960s, when Christie and Geis created the MACH test to assess utilitarianism (Christie & Geis, 1970), psychologists have referred to Machiavellianism as a duplicitous interpersonal style marked by a cynical disregard for morality and emphasis on self-interest and personal benefit. Further experiments revealed that in both experimental and real-world trials, respondents who agreed with the statements of the MACH test were more willing to act coldly and manipulatively (Christie & Geis, 1970). The originator of the term narcissism is Narcissus, a young male hunter who was so blinded by his beauty and greatness that he arrogantly hated the affection and devotion of others. This myth reflects the central characteristics of narcissism as it is understood today, namely, a mix of grandiosity, entitlement, supremacy, and superiority that harms interpersonal relationships (Campbell et al., 2010). In addition to these characteristics, individuals with increased narcissistic traits are characterized by malignant features, which are increased paranoia when it comes to evaluating people's behaviors, intents and aggressiveness (Kernberg, 1989). Raskin and Halls' (1979) effort to describe a subclinical variant of the DSM-defined personality disorder resulted in the concept of subclinical narcissism. The Narcissistic Personality Inventory (NPI) was created after items were refined on large samples of students. Literature supports the effective transition from clinical to subclinical construct (Morf & Rhodewalt, 2001). Psychopathy has its origins in psychiatry, Cleckley (1950), for example, used systemic analyses to describe a group of patients who exhibited enduring antisocial behavior, decreased empathy and guilt, and maladaptive and aggressive behavior, often hidden under a mask of superficial charm. Psychopathy's adaptation to the subclinical domain is the latest of the three (Hare, 1985; Lilienfeld & Andrews, 1996). The self-report psychopathy (SRP) scale elements were chosen to distinguish clinically diagnosed psychopaths from non-psychopaths (Hare, 1985). It was later tested in non-criminal samples and found to be accurate (Forth et al., 1996). Williams and Paulhus (2004) found that the SRP has the same four-factor formulation as the Psychopathy Check List (Hare, 1991), the benchmark of psychopathy assessment.

Despite their different backgrounds, the traits of the Dark Triad share a range of characteristics. All three have a psychologically malevolent personality with impulses toward self-promotion, emotional coldness, deception, and aggression of varying degrees. As subclinical narcissism, Machiavellianism, and subclinical psychopathy have been tied together as the Dark Triad; two measures have been established to assess these three components: The Dirty Dozen (DD; Jonason & Webster, 2010), which has just 12 items, and the Short Dark Triad (SD3; Jones & Paulhus, 2014), which has 27 items. Both measures have been demonstrated to have some significance in terms of statistical correlations with the main measures (i.e., NPI, MACH– IV, and SRP–III), though the DD (being the shortest scale) results worse than the SD3 in this respect (Maples, Lamkin, & Miller, 2014).

In recent years, a small number of neuroimaging investigations have focused on the elements of the Dark Triad separately, leading to the discovery of specific anatomical and functional changes in the brain consistent with the individual components of the Dark Triad. The basal ganglia (a reward center) left prefrontal cortex (regulation of emotional distress), bilaterally in the insula (the experience of disgust and the urge to inhibit negative emotions), and the right hippocampus and left parahippocampal gyrus (involved in learning and spatial information processing) all showed significant positive differences between high versus low Machiavellianism (Verbeke et al., 2011). These areas are linked to Machiavellian traits, such as dishonest political manipulation (e.g., doing whatever it takes to get what they want while avoiding detection, ensuring that their social standing is not negatively impacted). Moreover, according to Nestor et al. (2013), higher Machiavelli personality characteristics were linked to more gray matter volume in the left lateral orbital gyrus. According to social-cognitive and psychodynamic theories of narcissism, highly narcissistic people display neuronal activity related with the self-gratification (subcortical dopaminergic regions) (Oikawa et al., 2012; Berridge & Kringelbach, 2013) or conflicting emotion regulation (subcortical dopaminergic regions and anterior cingulate) (Cascio et al.,2015). In clinical narcissistic personality disorder, lower GM volume has been found in fronto-paralimbic brain regions like the left anterior insula, the rostral portion of the anterior cingulate cortex, and the median cingulate cortex than healthy controls. The left anterior insula seems to be a promising neuronal correlate of diminished social empathy, with implications for diagnosing and treating clinical narcissism (Schulze et al., 2013). In harmony with the study of Schulze et al. (2013), healthy individuals with narcissistic traits had differences in empathy-related brain areas, which is the anterior insula (Fan et al., 2011). When asked to mentally empathize with others, narcissistic subjects were shown to have dysfunctional anterior insula processing (Fan et al., 2011). In psychopathy, prior literature has mainly investigated the structural bases of psychopathy in antisocial individuals from forensic and psychiatric groups. Subcortical mechanisms such as the amygdala (Yang et al., 2009), parahippocampal gyrus and hippocampus have been shown to be altered because of psychopathic traits ((Ermer et al., 2013),). These results support the theory that psychopathy is linked to a fundamental impairment of emotional reactivity and associative processing caused by impaired affective-motivational mechanisms that depend on the amygdala and other integrated mechanisms (Marsh, 2013). In individuals with psychopathic characteristics, mixed findings have been documented. In people with psychopathic characteristics, the anterior cingulate cortex (ACC) has been found to be affected (Cope et al., 2012) or not affected (Glenn et al., 2010). Moreover, previous studies have found insula volume decreases (Oliveira-Souza et al.,2008), which may be related to empathic deficiencies in adults (Decety et al.,2013) and adolescents (Lockwood et al., 2013).

The use of mass univariate approaches to compare groups was one of the primary limitations of earlier neuroimaging experiments. Typically, researchers have used region of interest (ROI) or voxel-based approaches to compare mean imaging metrics between experimental groups and controls across brain areas. This method has advantages and disadvantages: morphometric methods, such as Voxel-based Morphometry (VBM), allow determining between-group variations in some brain regions; but, as a univariate approach, it compared distinct voxels across different individuals' brains without considering their interrelationships. VBM sensitivity from vast cortical regions to smaller subcortical areas is also significantly decreased (Aguilar-Ortiz et al., 2018). As a result, it is understandable that the previous findings' high uncertainty is most likely due to methodological differences and weaknesses. To research gray matter variations, source-based morphometry (SBM) is a multivariate alternative to voxel-based morphometry (VBM). SBM was first suggested by Xu and colleagues (Xu et al., 2009) to investigate schizophrenia patients. The significant disadvantage of VBM is that it is a univariate approach, which means it does not consider any info about the relationships between voxels and instead identifies voxels with a specific expected outcome. On the other hand, SBM is a data-driven multivariate process that recognizes information from multiple brain voxels and produces spatially independent sources regarding the localization of alterations. SBM can achieve this by spatially filtering the data, which VBM does not do. Furthermore, SBM outperforms VBM in terms of sensitivity and specificity (Xu et al., 2009), significantly when overlapping regions are present: SBM may allocate a single voxel to different sources, resulting in more precise data.

Given the mentioned limitations of univariate methodologies such as VBM, as well as the fact that the majority of anatomical studies assessing individual members of the Dark Triad brains use VBM (there are no SBM studies in the literature focused on Dark Triad), we have chosen to use SBM to examine Dark Triad. This study aimed to find spatially independent gray matter components that predict the Dark Triad on a whole-brain basis for the first time. To accomplish this, we will use the Short Dark Triad (SD3), a brief measurement of three socially aversive traits: Machiavellianism, subclinical narcissism, and subclinical psychopathy (Jones & Paulhus, 2014). We hypothesized that those common characteristics of the Dark Triad, such as psychologically malevolent personality with impulses toward self-promotion, emotional coldness, deception, and aggression, can be successfully predicted by brain features. Moreover, we predicted that spatially independent gray matter differences that predict the overall Dark Triad will be correlated with different components of the Dark Triad by considering the different definitions and origins of the three individual traits of the Dark Triad.

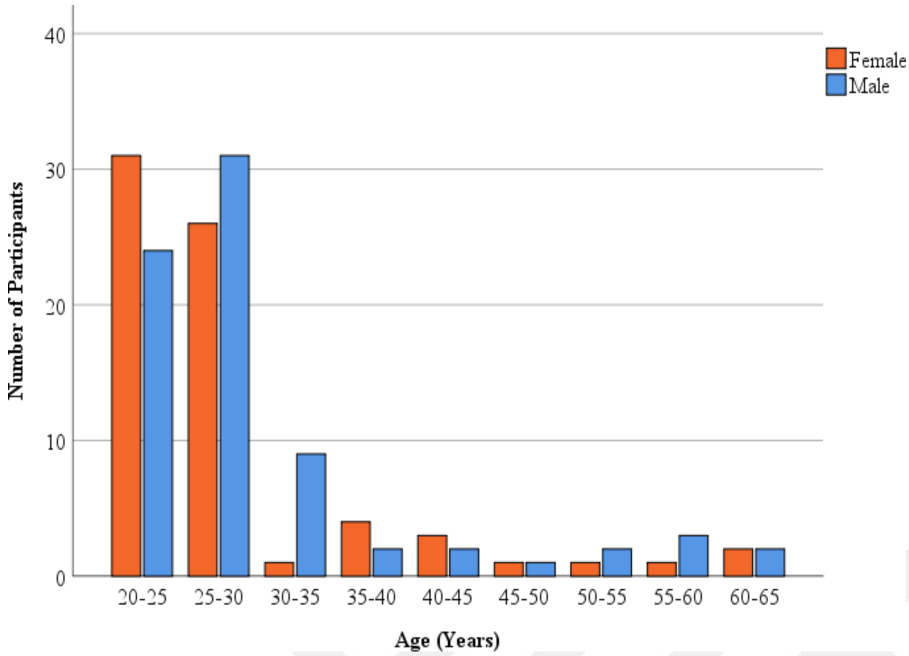
Method

Participants

146 native German-speaking participants took part in this study (70 females and 76 males, mean age=29.45 years, SD=9.81, age range 20–65 years). Figure 4 shows the age distribution of the male and female participants in the current study.

Figure 4

Age Distribution (5-year bins) of the Participants Split by Gender.



Participants were selected from the OpenfMRI database. A total of one 194 native German-speaking participants were included in the database, but 48 participants were excluded due to age matching and specific or suspected psychiatric disorders confirmed by Structured Clinical Interview-I SCID-I (Wittchen et al.1995). All participants were screened by phone regarding the exclusion criteria to assess their current study eligibility (see Box 1; Mendes et al., 2019, Sci Data, 6, p. 3). Participants who meet the eligibility requirements, including medical examination for MRI scanning and neurological background, were invited to the Max Planck Institute for Human Cognitive and Brain Sciences (MPI-CBS) and assessed for psychiatric history by using the Structured Clinical Interview for DSM-IV (SCID-I). Written informed consents which included their willingness to provide their data shared anonymously were delivered to the participants. Participants were compensated financially for their participation. The ethics committee at the University of Leipzig's medical faculty (097/15-ff) approved the research procedure.

Box 1

Exclusion criteria to prospective participants.

- History of psychiatric diseases that required inpatient treatment for longer than 2 weeks within the last 10 years (e.g., psychosis, attempted suicide, post-traumatic stress disorder)
- History of neurological disorders (incl. multiple sclerosis, stroke, epilepsy, brain tumors, meningoencephalitis, severe concussion)
- History of malignant diseases
- Intake of one of the following medications:
  - Any centrally active drugs (including Hypericum perforatum)
  - Beta- and alpha-blocker
  - Cortisol
  - Any chemotherapeutic or psychopharmacological medication
- Positive drug anamnesis (extensive alcohol, MDMA, amphetamines, cocaine, opiates, benzodiazepine, cannabis)
- Extensive testing experience at the MPI-CBS or other academic institution
- Past or present student of Psychology
- MRI exclusion criteria
  - Any metallic implants, braces, non-removable piercings
  - Tattoos
  - Pregnancy
  - Claustrophobia
  - Tinnitus
  - Surgical operation in the last 3 months

Note. Adapted from "A Functional Connectome Phenotyping Dataset Including Cognitive State and Personality Measures," Mendes, N., Oligschläger, S., Lauckner, M. *et al.*, 2019, *Sci Data*, *6*, p. 3 (https://doi.org/10.1038/sdata.2018.307). Creative Commons Attribution 4.0 International License.

Short Dark Triad (SD3)

The SD3 (see Appendix) is a quick assessment of traits associated with Dark Triad personalities. It has 27 statements that can be rated on a 5-point Likert scale (1=" strongly disagree" to 5=" strongly agree") (Jones and Paulhus, 2014). Nine items are devoted to measuring Machiavellianism, and the prestige, cynicism, alliance formation, and tactical calculations were all focused on within the Machiavellianism subscale, such as "Make sure your plans benefit you, not others." Nine items on the narcissism subscale focused on arrogance, egocentricity, and exhibitionism, such as "I know I am special because everyone tells me so." Antisocial behavior, unpredictable way of living, callous affects, and short-term manipulating such as "People who mess with me always regret it" were all assessed on the psychopathy subscale with nine items (see Appendix). It is crucial to highlight that the diagnosis is subclinical for the narcissism and psychopathy. The English version of the Short Dark Triad was translated into German. The Cronbach alpha values were used to assess the SD3's reliability. The reliabilities of the subscales were satisfactory; Machiavellianism, α=0.68 (English original: α=0.78), Narcissism, α=0.65 (English original: α=0.77), Psychopathy, α=0.59 for (English original: α=0.80). By summing the scores of the individual Dark Triad traits, we calculated SD3 Total Scores.

MRI Data Acquisition

Imaging data were acquired using a whole-body 3 Tesla scanner (Magnetom Verio, Siemens Healthcare, Erlangen, Germany) installed with a 32-channel Siemens head coil at the Day Clinic for Cognitive Neurology, University of Leipzig, and the scanner remained consistent and did not need any significant maintenance or modifications that would have a negative impact on the accuracy of the data acquired. A high-resolution structural scan, four resting-state fMRI scans, two gradient-echo field maps, and two pairs of spin-echo scans with reversed-phase encoding direction were acquired for each subject. A FLAIR sequence was used to get a low-resolution structural scan of each subject for clinical assessment. In the current study, structural magnetic resonance imaging (MRI) data were analysed. The high-resolution structural image was acquired by using a 3D MP2RAGE sequence (Marques et al. 2010) with the following parameters: voxel size=1.0 mm isotropic, FOV=256×240×176 mm, TR=5000 ms, TE=2.92 ms, TI1=700 ms, TI2=2500 ms, flip angle 1=4°, flip angle 2=5°, bandwidth=240 Hz/Px, GRAPPA acceleration with iPAT factor 3, pre-scan normalization, duration = 8.22 min.

The MPI-Leipzig Mind-Brain-Body (MPILMBB) database includes four fMRI (Functional Magnetic Resonance Imaging) scans, one sMRI ((Structural Magnetic Resonance Imaging) scan, and a wide range of state and trait phenotypic measurements, including mind-wandering, personality characteristics, and cognitive ability. In the current study, short dark triad (SD3) scale (Jones and Paulhus, 2014) and structural magnetic resonance imaging (MRI) data were analyzed.

Pre-processing of the Images

Pre-processing all images with SPM12 software (http://www.fil.ion.ucl.ac.uk/spm/software) and specific toolboxes was the first step in our analysis. Following a preliminary data quality inspection (to avoid severe artifacts that could easily influence the findings), each image was reoriented according to the origin and then segmented into grey matter (GM), white matter (WM), and cerebrospinal fluid (CSF). Because our purpose was to investigate gray matter anomalies, we exclusively used these images in our study from that point on. Then, as a preliminary template, a mean of all the images was estimated so that nonlinear deformations could be generated for warping all the GM pictures to match each other. This process, which might be used as an alternative to SPM's typical registration procedures, was created utilizing Diffeomorphic Anatomical Registration through Exponential Lie algebra (DARTEL) tools. Finally, DARTEL images were normalized to MNI space using spatial smoothing (full width at half maximum of Gaussian smoothing kernel [8, 8, 8]) (Pappaianni et al., 2017). Images were ready to be processed using Source-Based Morphometry.

Source-Based Morphometry (SBM)

SBM can identify differences in gray matter across individuals in distinct networks since it considers the interrelationships between distinct voxels (Xu et al., 2009). It operates on the whole brain, detecting and deconstructing mixed signals derived from structural scans using Independent Component Analysis (ICA). SBM retains spatial correlation between various brain areas while operating as a spatial filter in this way (Gupta et al., 2018). These benefits of SBM indicate that it is better than VBM since it reduces noise in findings and considers the link between several voxels (Grecucci et al., 2016; Pappaianni et al., 2017). The mixed signal from pre-processed images was then separated via Independent Component Analysis (ICA) to optimize the identifying the spatially different sources. This stage was carried out by Group ICA, which is an fMRI toolbox (GIFT, http://mialab.mrn.org/software/gift). The Infomax algorithm was applied to increase IC identification from image signal info (Bell and Sejnowski, 1995; Lee et al., 1999); the ICASSO algorithm was selected to examine the ICA algorithm's reliability. In the ICASSO analysis setting, both RandInit and Bootstrap options were selected, and ICA was performed hundred times with a minimum cluster size of 2.

The core objective of SBM is to generate a numerical matrix that represents each component's GM volume for each subject. SBM produces a matrix once the analysis has been completed, with columns referring to the sources and rows referring to the subjects. This matrix shows how each subject expresses a particular IC. Statistical analyses were performed at this stage to identify the major sources that differed across participants. The Talairach atlas in the GIFT software was used to get anatomical descriptions of individual components.

Statistical Analysis

SPSS version 26.0 was used to perform all statistical analyses (IBM Corp., Armonk, NY). An independent sample t-test was used to analyze gender differences in the overall Dark Triad scores. For statistical analysis, we utilized the mixing matrix because each column of the mixing matrix includes the loading parameters indicating each component's contributions to the 146 participants. Multiple regression analysis was applied to each column to investigate which components predict the overall Dark Triad. Partial correlation controlling for gender and age, was performed then to examine the relationship between the independent components that predicted the overall Dark Triad score, and the subclinical narcissism, subclinical Machiavellianism, and subclinical psychopathy traits.

Results

Descriptive Statistics

The Dark Triad three scales can be merged to form an overall Dark Triad score, as already done (Jonason et al., 2009); therefore, we have chosen to consider them as an overall Dark Triad score. Table 2 displays the descriptive statistics of the Dark Triad traits and the overall Dark Triad score.

Table 2

Descriptive Statistics

	Mean	**SD**
Machiavellianism	20.85	3.33
Subclinical Narcissism	24.59	4.69
Subclinical Psychopathy	18.47	4.03
Overall Dark Triad Score	63.92	8.50

Previous research has found that all traits of the Dark Triad are more prevalent in males than females (Grijalva et al., 2015; Cale & Lilienfeld, 2002; Nicholls et al., 2005; Krampen et al., 1990). Although the Dark Triad traits are studied separately to understand gender differences, there is a need to explain the gender disparities of the overall Dark Triad. Table 3 displays the descriptive results separated by gender for the three traits of the Dark Triad and the overall Dark Triad score.

Table 3

Mean and Standard deviation on the Subscales of Dark Triad and Overall Dark Triad among Female and Male

Gender	Machiavellianism	Subclinical Narcissism	Subclinical Psychopathy	Overall Dark Triad Score
Male (N=76)				
Mean	21.03	25.12	19.22	65.37
SD	2.79	4.83	3.88	8.23
Female (N=70)				
Mean	20.67	24.01	17.67	62.36
SD	3.86	4.51	4.07	8.57

An independent sample t-test was conducted to assess gender differences in the overall Dark Triad. There was a significant difference between female (*M* = 62.36, *SD* = 8.57) and male (*M* = 65.37, *SD* = 8.23) in the overall Dark Triad score, $t\ (144) = -2.164$, $p = .03$. According to these findings, male participants have an overall Dark Triad than female participants.

Source-based Morphometry

Using the minimal description length (MDL) criterion in the SBM analysis, 16 unique spatial components with covarying grey matter patterns were identified; a matrix composed of 146 rows (the participants) and 16 columns (the sources) was obtained, and 14 components with Iq > 0.9 indicating a highly stable ICA decomposition (component 15 and 16 eliminated) included in the statistical analysis. Using Pearson's parametric correlation, the SBM findings were then correlated with the overall Dark Triad Scores.

Two Sources resulted in being significantly correlated with overall Dark Triad scores (p values < 0.05). Increased GMCs in Source 6 (see Figure 4 and Figure 6) including Posterior Cingulate, Cuneus, Extra-Nuclear, Precuneus, Sub-Gyral, Inferior and Middle Occipital Gyrus, Lingual Gyrus, Parahippocampal Gyrus, Lateral Ventricle, and decreased GMCs in Source 6 including Middle Frontal Gyrus, Sub-Gyral and Inferior Frontal Gyrus are correlated with increased overall Dark Triad ($r = .220$, *p-value* = 0.007). Moreover, increased GMCs in Source 14 (see Figure 5 and Figure 7) including Precuneus, Sub-Gyral, Angular Gyrus, Inferior and Superior Parietal Lobule, Middle and Superior Occipital Gyrus, Middle Temporal Gyrus, Cuneus, and decreased GMCs in source 14 including Sub-Gyral, Cerebellar Tonsil, Precuneus, Extra-Nuclear, Culmen, Posterior Cingulate, Cingulate Gyrus, Inferior Parietal Lobule, Anterior Cingulate, Supramarginal Gyrus, Inferior Semi-Lunar Lobule, Middle Temporal Gyrus, Lateral Ventricle are correlated with increased overall Dark Triad (r = .174, *p-value* = 0.03).

After eliminating multicollinearity with a tolerance level of 0.1, multiple regression analyses were performed to predict total Dark Triad Scores with all 14 ICA parameters, age, and gender, which were entered simultaneously into the regression models. Overall Dark Triad was significantly predicted by the regression models (F = 1.784, *p-value*= 0.040), with the loading coefficients of IC6 and IC14.

Partial correlation analysis was conducted between the three traits of the Dark Triad, overall Dark Triad, component 6, and component 14 by controlling the effect of the gender and age to separate the neural correlates of the Dark Triad trait. Component 6 positively correlated with the subclinical narcissism scores ($r = .172$, *p-value* = 0.040), and overall Dark Triad ($r = .204$, *p-value* = 0.015). Component 14 positively correlated with the Machiavellism scores ($r = .180$, *p-value* = 0.031), and overall Dark Triad ($r = .191$, *p-value* = 0.022). There was no significant relationship between subclinical psychopathy and the ICs.

Table 4

Anatomical description of the independent components.

IC6 (Positive Regions)			
Anatomical regions	Brodmann Area	volume (cc)	random effects: Max Value and MNI (x, y, z)
Posterior Cingulate	23, 30, 31	2.0/3.5	7.1 (-21, -59, 10)/8.3 (18, -65, 12)
Cuneus	7, 17, 18, 19, 23, 30	5.2/8.3	6.9 (-12, -72, 12)/8.0 (15, -68, 13)
Extra-Nuclear	*	0.6/0.8	6.6 (-21, -55, 8)/6.9 (25, -55, 8)
Precuneus	7, 23, 31	1.2/2.0	5.6 (0, -73, 24)/6.2 (3, -73, 22)
Sub-Gyral	*	0.4/0.9	4.8 (-15, -59, 21)/5.8 (13, -57, 21)
Middle Occipital Gyrus	18, 19	1.6/2.7	5.6 (-31, -84, 10)/5.4 (33, -79, 15)
Lingual Gyrus	17, 18	0.6/3.4	5.0 (-19, -52, 5)/5.3 (10, -91, -4)
Parahippocampal Gyrus	30	0.0/0.3	-999.0 (0, 0, 0)/5.0 (21, -51, 5)
Lateral Ventricle	*	0.1/0.3	3.9 (-27, -55, 8)/5.0 (28, -58, 10)
Inferior Occipital Gyrus	17, 18	0.0/0.6	-999.0 (0, 0, 0)/4.9 (18, -89, -8)
Cingulate Gyrus	*	0.0/0.1	-999.0 (0, 0, 0)/4.8 (16, -54, 26)
Middle Temporal Gyrus	*	0.1/0.3	3.6 (-37, -73, 19)/4.4 (36, -79, 18)
Middle Frontal Gyrus	*	0.0/0.1	-999.0 (0, 0, 0)/4.0 (34, 25, 33)
Angular Gyrus	*	0.1/0.0	3.7 (-43, -56, 37)/-999.0 (0, 0, 0)
Fusiform Gyrus	*	0.0/0.1	-999.0 (0, 0, 0)/3.6 (25, -91, -11)
Superior Temporal Gyrus	*	0.0/0.1	-999.0 (0, 0, 0)/3.5 (55, -53, 14)
IC6 (Negative Regions)			
Anatomical regions	Brodmann Area	volume (cc)	random effects: Max Value and MNI (x, y, z)
Middle Frontal Gyrus	9	0.1/0.7	3.8 (-37, 13, 26)/5.1 (37, 13, 28)
Sub-Gyral	*	0.0/0.2	-999.0 (0, 0, 0)/4.4 (37, 16, 25)
Inferior Frontal Gyrus	*	0.2/0.1	4.3 (-37, 10, 29)/4.2 (40, 10, 29)
IC14 (Positive Regions)			
Anatomical regions	Brodmann Area	volume (cc)	random effects: Max Value and MNI (x, y, z)
Precuneus	7, 19, 31	1.7/1.7	9.2 (-25, -62, 35)/12.3 (28, -59, 36)
Sub-Gyral	*	1.6/2.9	8.7 (-27, -65, 32)/10.5 (27, -56, 39)
Angular Gyrus	39	0.0/0.2	-999.0 (0, 0, 0)/7.7 (33, -59, 35)
Superior Parietal Lobule	7	0.1/0.6	5.6 (-24, -62, 43)/7.7 (28, -58, 43)

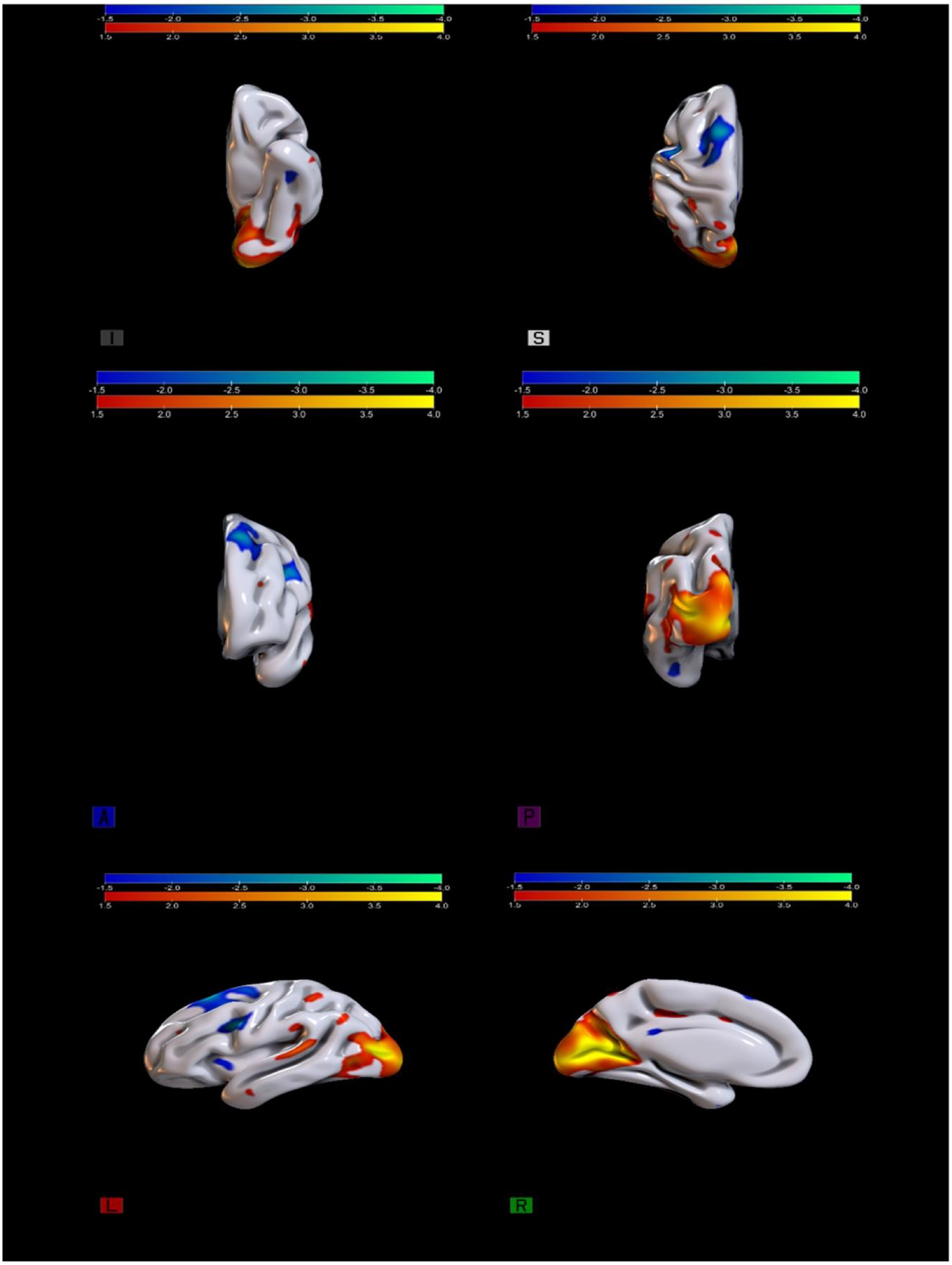
Middle Temporal Gyrus	*	0.0/0.4	-999.0 (0, 0, 0)/7.6 (31, -75, 20)
Inferior Parietal Lobule	39, 40	0.0/0.3	-999.0 (0, 0, 0)/5.3 (34, -62, 40)
Middle Occipital Gyrus	19	0.0/0.2	-999.0 (0, 0, 0)/5.1 (31, -72, 17)
Cuneus	18	0.4/0.2	4.4 (-22, -70, 31)/4.8 (25, -78, 23)
Superior Occipital Gyrus	*	0.0/0.2	-999.0 (0, 0, 0)/4.7 (34, -74, 29)
Uncus	28	0.1/0.0	4.0 (-15, -3, -25)/-999.0 (0, 0, 0)
Middle Frontal Gyrus	*	0.1/0.0	3.7 (-37, 16, 38)/-999.0 (0, 0, 0)
Precentral Gyrus	*	0.0/0.1	-999.0 (0, 0, 0)/3.7 (30, -19, 49)
Postcentral Gyrus	2	0.0/0.1	-999.0 (0, 0, 0)/3.7 (36, -29, 41)
Cerebellar Tonsil	*	0.0/0.1	-999.0 (0, 0, 0)/3.6 (27, -55, -41)

IC14 (Negative Regions)

Anatomical regions	Brodmann Area	volume (cc)	random effects: Max Value and MNI (x, y, z)
Sub-Gyral	*	0.6/1.6	6.9 (-16, -59, 21)/8.3 (19, -57, 21)
Cerebellar Tonsil	*	0.8/0.0	8.1 (-42, -40, -36)/-999.0 (0, 0, 0)
Precuneus	7, 31	1.0/1.7	6.2 (-15, -61, 24)/7.7 (16, -57, 24)
Extra-Nuclear	*	0.2/1.0	5.7 (-13, -56, 18)/7.5 (19, -54, 18)
Culmen	*	1.0/0.1	6.6 (-45, -39, -30)/3.6 (33, -36, -26)
Posterior Cingulate	30, 31	1.2/2.2	6.3 (-16, -59, 17)/6.6 (19, -58, 15)
Cingulate Gyrus	31	0.1/0.3	4.3 (-7, 22, 28)/5.8 (16, -54, 26)
Inferior Parietal Lobule	*	0.0/0.4	-999.0 (0, 0, 0)/5.5 (48, -44, 27)
Anterior Cingulate	32	0.6/0.0	4.4 (-6, 39, 2)/-999.0 (0, 0, 0)
Supramarginal Gyrus	*	0.0/0.4	-999.0 (0, 0, 0)/4.3 (50, -44, 30)
Inferior Semi-Lunar Lobule	*	0.6/0.0	4.2 (-15, -62, -40)/-999.0 (0, 0, 0)
Middle Temporal Gyrus	*	0.0/0.1	-999.0 (0, 0, 0)/4.1 (42, -69, 17)
Lateral Ventricle	*	0.0/0.1	-999.0 (0, 0, 0)/3.8 (28, -55, 8)

Figure 4

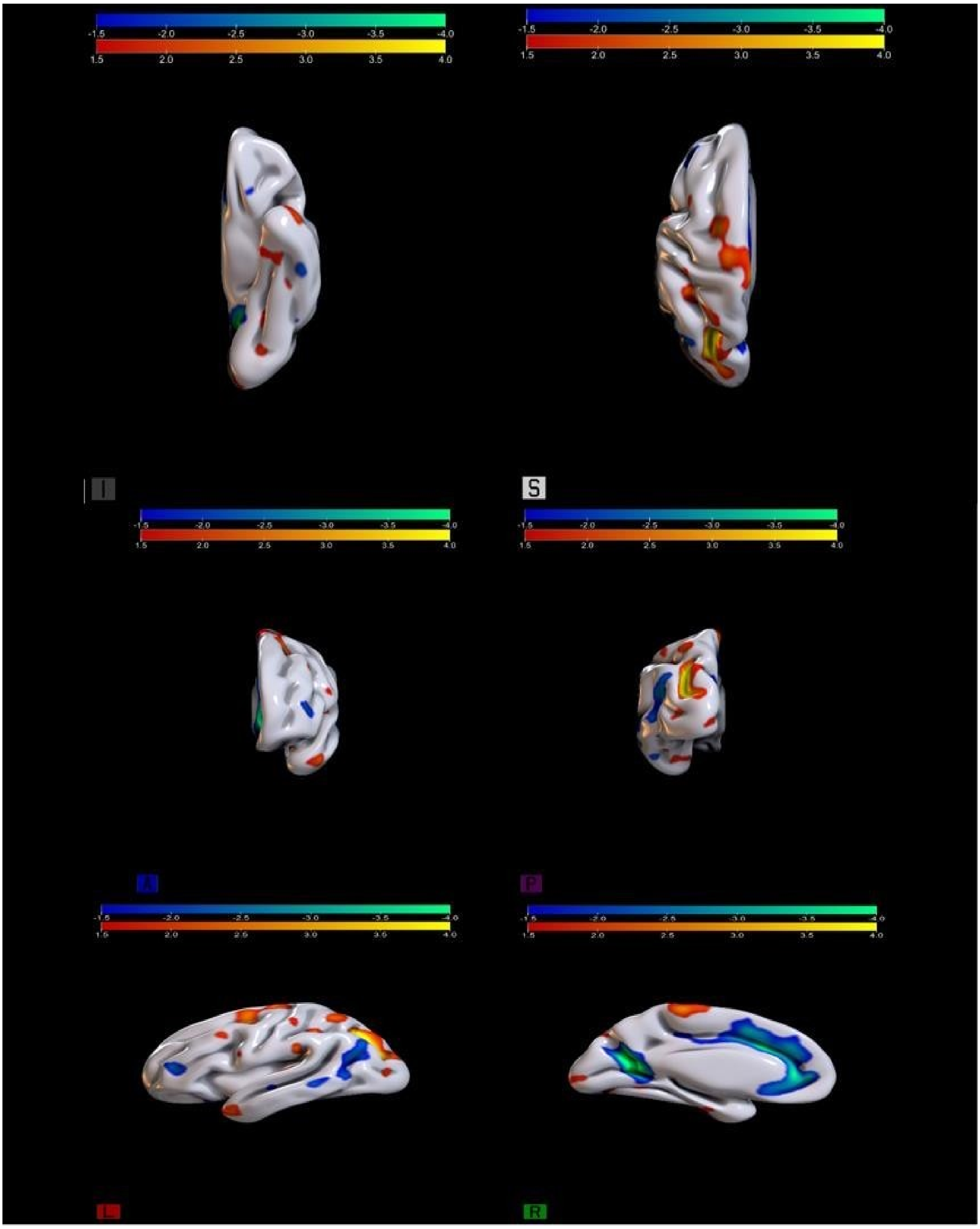
Independent Component 6



Note. The regions that displayed increased GMCs are shown in red, and decreased GMCs are shown in blue.

Figure 5

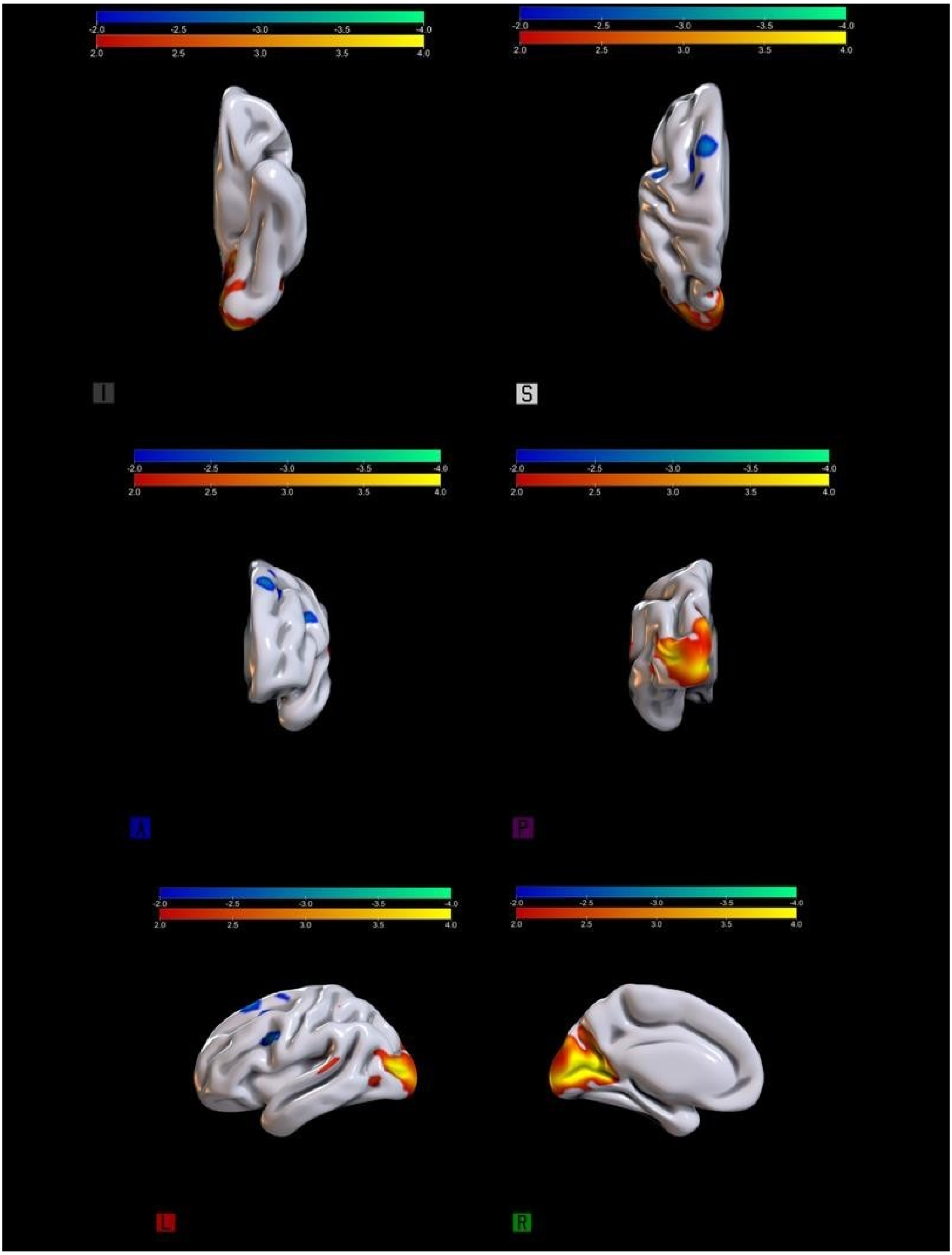
Independent Component 14



Note. The regions that displayed increased GMCs are shown in red, and decreased GMCs are shown in blue.

Figure 6

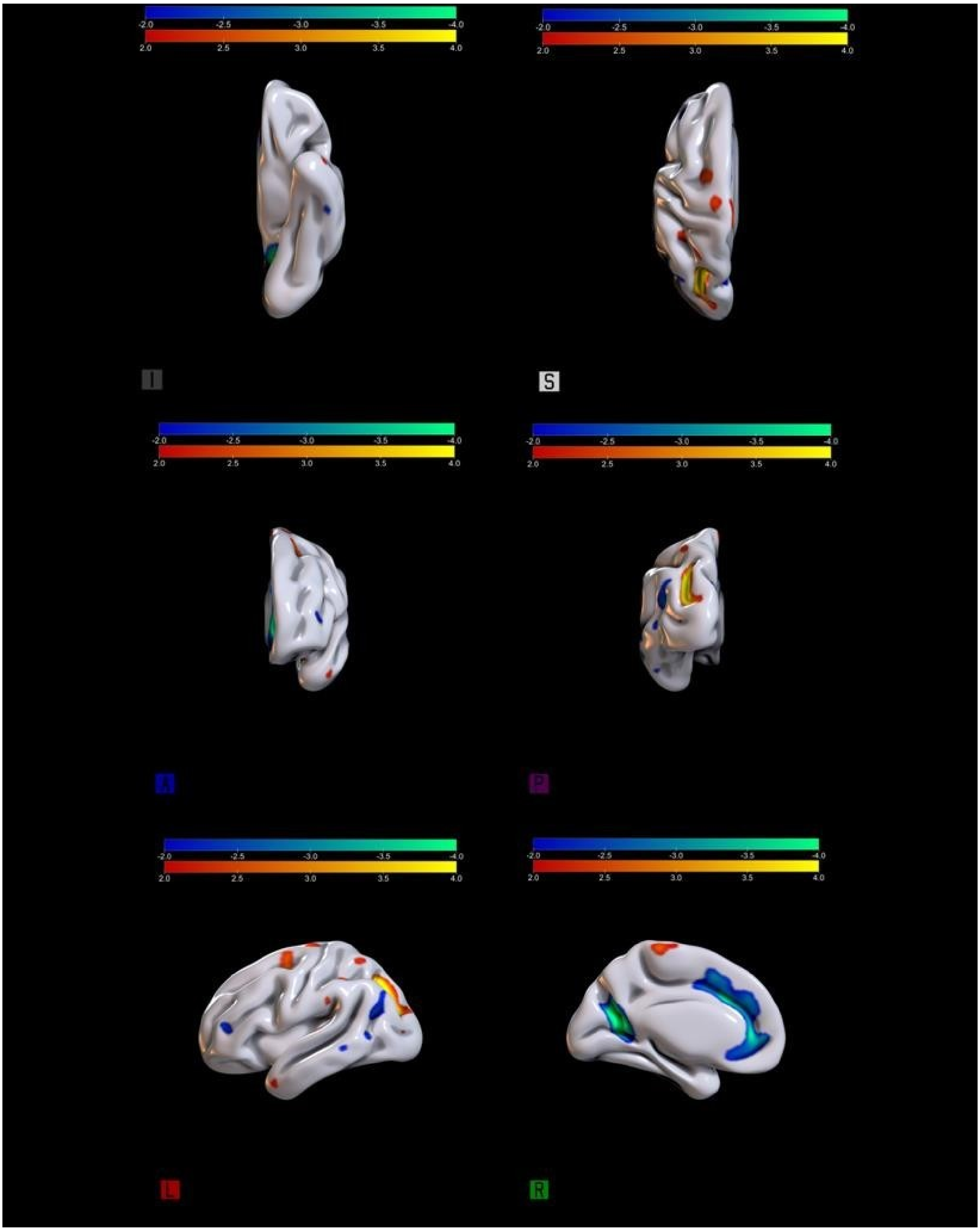
Independent Component 6



Note. IC6 is thresholded at z > 2. The regions that displayed increased GMCs are shown in red, and decreased GMCs are shown in blue .

Figure 7

Independent Component 14



Note. IC14 is thresholded at z > 2. The regions that displayed increased GMCs are shown in red, and decreased GMCs are shown in blue .

Discussion

Paulhus and Williams (2002) used the phrase "Dark Triad" to refer to the personality traits of subclinical narcissism, Machiavellianism, and subclinical psychopathy. Despite being relatively interconnected, each trait has distinctive features. The desire for achievement in competing and a grandiose level of self describes subclinical narcissism (Raskin & Terry, 1988). Machiavellianism is characterized by adopting and applying a deceptive, manipulative, and exploitative communication style in interpersonal relationships (Christie & Geis, 1970). Hare et al., (2012) define subclinical psychopathy as a callous, cold, and aggressive temperament. All of them have one thing in common: impulses toward self-promotion, emotional coldness, deception, and aggression that leave little room for empathy (Jakobwitz & Egan, 2006; Jones & Paulhus, 2011).

A very few imaging studies have been focused on the traits of the Dark Triad individually, resulting in the inconsistent findings of distinct anatomical and functional alterations associated with subclinical narcissism (Oikawa et al., 2012; Berridge & Kringelbach, 2013), subclinical psychopathy (Yang et al., 2009; Ermer et al., 2013; Ermer et al., 2012) and Machiavellianism (Verbeke et al., 2011; Nestor et al., 2013). Different factors might be accountable for the inconsistent findings of structural alterations correlated with the Dark Triad traits. For instance, many morphological results are derived from VBM that used a univariate strategy. These findings presume that regional differences in brain morphology across participants are spatially separate, and thus VBM ignores the correlation or interrelation among dispersed areas. As a result, a multivariate statistical method is known as source-based morphometry (SBM), a form of unsupervised machine learning would be a preferable choice, as SBM provides a unique way to investigate the trends of morphometric alterations in grey matter (Xu et al., 2009). The word ‘source’ in this technique refers to distinct spatial components that display similar trends of morphometric fluctuation within individuals and are produced without any prior assumption. SBM shows related sub-systems in the brain thanks to a multivariate basis (Caprihan et al., 2011). Although some previous investigations have employed SBM to explore diagnostic characteristics in different psychiatric conditions (Kubera et al., 2014; Wolf et al., 2014), there have been no SBM investigations in the literature that focuses on Dark Triad traits. Thanks to the advantages of the multivariate approach, we used SBM to explore the patterns of morphometric changes in grey matter associated with the Dark Triad (SBM). Indeed, we were motivated by two major goals: the first was to examine the spatially independent gray matter differences that predict the overall Dark Triad, and the second was to separate these components in terms of the Dark Triad subscales. To the best of our knowledge, this is the first study that use a multivariate morphometric procedure to examine Dark Triad traits, and the first study examines the neural basis of the overall Dark Triad.

In this study, we found that variations of GMC in IC 6 and IC 14 are associated with higher scores of the Dark Triad. It is worth mentioning that our findings suggest a trend of concurrent alterations in both directions (increase and decrease) in GMC that predict the increasing overall Dark Triad. Moreover, our correlation analysis shows that subclinical narcissism is correlated with IC6 and subclinical psychopathy, and Machiavellianism is correlated with IC14 and subclinical psychopathy, providing the opportunity of separating the components in terms of specific Dark Triad traits. Although IC 6 and IC 14 did not correlate with subclinical psychopathy, the correlations between the Dark Triad subscales suggest that subclinical psychopathy is blended with the other two subscales.

First of all, increased GMC in IC 6 mainly includes occipital, temporal areas, and angular gyrus predicts the overall Dark Trait increases and positively correlates with the subclinical narcissism. According to Kumari et al. (2009), individuals with aggressive and antisocial characteristics displayed increased activity in the occipital and temporal regions (specifically middle and superior temporal gyrus, middle and inferior occipital gyrus) under the circumstances that they felt threatened. Taken together, these findings indicate that there is a positive relationship between the neural activations of these regions and antisocial tendencies. Moreover, one of the main self-regulation techniques used by subclinical narcissists is the self-serving bias, which links the attribution of achievement to the self and protects the grandiose sense of self by projecting the cause of failures to external sources (Tamborski et al., 2012). The angular gyrus has been shown to become activated in self-relevant cognition, episodic memory (Andrews-Hanna et al., 2010; Humphreys and Lambon Ralph, 2015), and emotion regulation by forming self-serving memories (Kohn et al., 2014). Increased GMC in the angular gyrus can be explained by the self-serving biases frequently used by individuals with subclinical narcissistic traits. Additionally, a GMC increase in the fusiform gyrus was also found as a possible morphological underpinning of the overall Dark Triad. Previous fMRI research has linked increased GMV in the fusiform gyrus to antisocial tendencies. The fusiform gyrus is crucial in the process of social comparison (Sabatinelli et al., 2011; Schwarz et al., 2013; Shkurko, 2013) and emotional states of shame and embarrassment (Takahashi et al., 2004; Michl et al., 2014). It is also suggested that the fusiform gyrus is a center of perceptions related to the moral standing of others which is very important for individuals with subclinical narcissism traits to create good first impressions (Singer et al., 2004).

Moreover, a higher overall Dark Triad predicted by decreased GMC in the IC 6 includes middle and inferior frontal gyrus (BA9). According to the lesion studies, the frontal gyrus is essential for inhibitory control (Clark et al., 2007; Aron et al. 2003), and Swick et al. (2008) demonstrated that patients with impairments in the frontal gyrus reacted more frequently on NoGo trials because of the decreased inhibitory control which leads to the impulsive behavioural patterns. According to the meta-analysis findings, the hypothesis that subclinical narcissism and subclinical psychopathy may be characterized in a generalized view of reduced behavioural inhibition and high impulsivity is supported (Glenn & Sellbom, 2015). Individuals with narcissistic personality traits socialize with others impulsively to create favourable initial impressions (Friedman et al., 2006, Paulhus, 1998). Their impulsiveness has both positive and negative effects in the long period since they are both enthusiastic and impulsive (Foster & Trimm, 2008). Subclinical psychopathy as a concept is more consistent with problematic impulsive behaviours. According to Hare et al. (1990), subclinical psychopathy is related to reduced conscientiousness and impaired self-control caused by impulsivity. On the other hand, Machiavellianism is characterized by manipulative behaviours which require a sense of self-control and decreased impulsivity which separates Machiavellism from other Dark Triad traits.

Additionally, increased GMC in IC 14 (distributed regions of frontal, parietal, and occipital lobe) predict a considerable variation in the overall Dark Triad and correlated with the Machiavellianism subscale. To begin with, an increase in GMC in the inferior parietal lobule was discovered as a possible neural predictor of increased overall Dark Triad. This region is considered to include mirror neurons (Molenberghs et al.,2012), implying that disruption in this area causes a variety of social deficiencies related to the Dark Triad's antisocial characteristics. For instance, the inferior parietal lobule is actively engaged in gaze processing (Pelphrey et al., 2003, 2004), action perception in recognizing intentions of other individuals (Gallese et al., 2004), understanding others' perceptions (Mende-Siedlecki et al., 2013), anticipating others' behavior from their eye movements (Ramsey et al., 2012). It is reasonable to conclude that Machiavellians can effectively detect other people's intentions and create better interpretations of social circumstances (Davies and Stone, 2003; Czibor and Bereczkei, 2012) to manipulate in the benefit of their personal goals (Fehr et al., 1992; Jones and Paulhus, 2009). Increased GMC in the superior parietal lobule was also predicting increases in the overall Dark Triad. The superior parietal lobule, which is typically recruited in parallel with the inferior parietal lobule (Culham et al., 1998), is engaged in visual attention (Molenberghs et al., 2007) and has been found to show increased activation for frightened responses in those who have antisocial tendencies (White et al., 2012). In addition, increased GMC in the postcentral gyrus related to the increased overall Dark Triad is demonstrated. According to previous findings, the postcentral gyrus is correlated with emotional regulation and empathy (Bernhardt and Singer, 2012; Morelli et al., 2014; Sarkheil et al., 2013). As a result, this anomaly might be linked to a disruption in empathy and emotional regulation in individuals with increased overall Dark Triad. The higher GMC in the indicated regions may contribute to reducing the negative emotions experienced by Machiavellian. They can use spatial attention to re-evaluate the social and spatial cues to analyze the social circumstances, and they can use the analyzed cues to suppress their actual emotions in certain situations while expressing them in other circumstances (Griffiths, 2003, 2004).

Furthermore, we found that higher overall Dark Triad predicted by decreased GMC in the IC 14, mainly anterior cingulate, precuneus, and posterior cingulate. Enhanced activation in the anterior cingulate cortex was connected to deceptive moral choices (Abe and Greene, 2014). Other investigations have consistently demonstrated that the anterior cingulate becomes activated in fraudulent actions (Ding et al., 2013; Hu et al., 2015). Hence, individuals with increased overall Dark Triad may be less responsive to the adverse effects of ethical violations due to decreased GMC in the anterior cingulate and thus tend to adapt deceitful behaviors. According to the studies on the Dark Triad, Machiavellianism and subclinical psychopathy are correlated with the deceitful interpersonal relationship (Kashy and DePaulo, 1996; Baughman et al., 2014). Moreover, decreased GMC was observed in the precuneus and posterior cingulate, related to the increased overall Dark Triad. The precuneus, as well as the posterior cingulate, has been proposed to be crucial in self-awareness (Lou et al., 2004), and prior imaging investigations have revealed that the precuneus and posterior cingulate is engaged in a variety of cognitive processes involving self-awareness (Cavanna, & Trimble, 2006; Buckner, & Carroll, 2007) and is required for conscious awareness (Vogt, & Laureys, 2005). One of the characteristics of subclinical psychopathy is inconsistent self-awareness which originates from a flexible, imprecise, and unreliable self-identity (Cooke & Logan, 2018; Campbell et al., 1996). Christie and Geis (1970) showed that people with high degrees of Machiavellianism are less concerned with maintaining a stable self-identity than people with lower levels of Machiavellianism. A flexible sense of self may have an adaptive function since it enables the individual to adjust in terms of the different circumstances and be adaptable in implementing the best strategies. Individuals with increased levels of the Dark Triad characteristics have an intense extrinsic focus, which means they avoid examining their inner self and are instead extremely concerned about the external world and gaining everything they desire from other individuals. This significant emphasis on the outside world may prove to be a major barrier to building a strong and coherent sense of self.

Finally, the effect of gender and age on the Dark Trait traits was investigated. In the literature, studies focused on the Dark Triad individually and reported that men have higher levels of subclinical psychopathy (Cale & Lilienfeld, 2002; Nicholls et al., 2005), subclinical narcissism (Grijalva et al., 2015), and Machiavellianism scores (Krampen et al., 1990). In the literature, gender differences were examined separately on the traits of the Dark Triad but not collectively. Individual Dark Triad traits are analyzed to examine gender differences, but the gender differences of the overall Dark Triad should be explained. We found that males have a higher overall Dark Triad than females, as it is already evidenced separately for the traits of the Dark Triad, which might be due to various factors. Firstly, there might be physiological differences, such as greater testosterone levels in males, which leads to more aggressive behaviors (Jonason & Davis, 2018). Secondly, it is likely that antisocial behavior, as defined by the Dark Triad, is more frequent in males than in females. Lastly, gender differences might be related to societal factors such as expected gender norms (Muris et al., 2017).

Although there is a narrow focus on the age patterns in Dark Triad, empirical evidence supports that there is a negative correlation between the Dark Triad traits and age (Barelds, 2016, Craker and March, 2016). Because of changes in social and cultural roles, less aggressive and antisocial behavior may be valued more as one gets older (Roberts & Wood, 2006). As explained by the life-history concepts, decreased levels of antisocial characteristics might represent an adjustment to a contextually more stable setting. Hormonal changes might also be the cause (Fabbri et al., 2016; Handelsman et al., 2016) because decreased testosterone levels in older people may be the biological reason for a reduced predisposition for violent and deviant behavior. A complex combination of psychological and physiological influences is most likely responsible for the negative relationship between age and the Dark Triad traits.

In this study, there are several strengths thanks to the using SBM as a multivariate approach to investigate changes in structural networks associated with Dark Triad since multivariate approaches have been evidenced to offer benefits not offered by univariate approaches (Kasparek et al., 2010). For instance, because all statistical investigation is conducted on a summarized matrix rather than on individual voxels, the multiple comparison issues present in univariate approaches are eliminated. Furthermore, identifying fundamental interactions between areas with comparable characteristics such as GMC can enable us to understand the structural basis of the overall Dark Triad and differentiate these areas in terms of Dark Triad traits thanks to the multivariate approach. Moreover, SBM enables noise reduction in the findings by spatially eliminating artifactual components, which provides less noise in the selected sources (Xu et al., 2009). To conclude, SBM is an effective approach for finding areas with comparable fundamental variability in gray matter across participants, and it can be a multivariate alternative to VBM with all the benefits described previously.

Certain limitations need to be stated regarding our study. Firstly, we utilized one psychometric test to assess Dark Triad characteristics. More detailed research might combine several measures to provide varying degrees of the portrayal of the Dark Triad traits by minimizing potential limitations associated with specific Dark Triad measurements. The second limitation of the current study is that our sample was very young, which prevented us from analysing the impact of age on the Dark Triad characteristics. A further study should include a greater number of elderly subjects to evaluate the emergence of Dark Triad traits over the lifetime. From the viewpoint of personality science, it would indeed be useful to compare the Dark Triad traits and other mainstream personality characteristics, which could provide a valuable understanding of the age-related variations between the Dark Triad and other personality traits.

In conclusion, alterations in morphological circuits related to Dark Triad are examined using source-based morphometry (SBM) as a form of unsupervised machine learning that can identify homogenous clusters and effectively identify the complex and unexplained distributed patterns of

GMC without previous information (Arbabshirani et al., 2016). Both increases and reductions in the grey matter related to the increased overall Dark Triad have been identified. Our findings indicate that the Dark Triad characteristics such as aggressive and antisocial behaviors, violating moral standards, and empathy impairment are likely related to GMC variations in multiple sub-systems (IC6 and IC 14). Furthermore, our findings show that variants of GMC in various sub-systems can be distinguished, with IC 6 being associated with subclinical narcissism and IC 14 being associated with Machiavellianism.

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Appendix

SD3 – 27 items

Please rate your agreement or disagreement with each item using the following guidelines.

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree

Machiavellianism subscale

1. It's not wise to tell your secrets.

2. Generally speaking, people won’t work hard unless they have to.

3. Whatever it takes, you must get the important people on your side.

4. Avoid direct conflict with others because they may be useful in the future.

5. It’s wise to keep track of information that you can use against people later.

6. You should wait for the right time to get back at people.

7. There are things you should hide from other people because they don’t need to know.

8. Make sure your plans benefit you, not others.

9. Most people can be manipulated.

Narcissism subscale

1. People see me as a natural leader.

2. I hate being the center of attention. (R)

3. Many group activities tend to be dull without me.

4. I know that I am special because everyone keeps telling me so.

5. I like to get acquainted with important people.

6. I feel embarrassed if someone compliments me. (R)

7. I have been compared to famous people.

8. I am an average person. (R)

9. I insist on getting the respect I deserve.

Psychopathy subscale

1. I like to get revenge on authorities.

2. I avoid dangerous situations. (R)

3. Payback needs to be quick and nasty.

4. People often say I'm out of control.

5. It's true that I can be mean to others. (or I enjoy having sex with people I hardly know.)

6. People who mess with me always regret it.

7. I have never gotten into trouble with the law. (R)

8. I like to pick on losers.

9. I'll say anything to get what I want.