2023-07-31

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Published in:
Social Neuroscience

DOI:
10.1080/17470919.2023.2242094

Publication date:
2023

Document version:
Publisher's PDF, also known as Version of record

Social Neuroscience

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/psns20

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To cite this article: Khanitin Jornkokgoud, Teresa Baggio, Md Faysal, Richard Bakiaj, Peera Wongupparaj, Remo Job & Alessandro Grecucci (2023) Predicting narcissistic personality traits from brain and psychological features: A supervised machine learning approach, Social Neuroscience, 18:5, 257-270, DOI: 10.1080/17470919.2023.2242094

To link to this article: https://doi.org/10.1080/17470919.2023.2242094

Published online: 31 Jul 2023.

SOCIAL NEUROSCIENCE
2023, VOL. 18, NO. 5, 257–270
https://doi.org/10.1080/17470919.2023.2242094

Routledge
Taylor & Francis Group

RESEARCH PAPER

Predicting narcissistic personality traits from brain and psychological features: A supervised machine learning approach

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ABSTRACT

Narcissism is a multifaceted construct often linked to pathological conditions whose neural correlates are still poorly understood. Previous studies have reported inconsistent findings related to the neural underpinnings of narcissism, probably due to methodological limitations such as the low number of participants or the use of mass univariate methods. The present study aimed to overcome the previous methodological limitations and to build a predictive model of narcissistic traits based on neural and psychological features. In this respect, two machine learning-based methods (Kernel Ridge Regression and Support Vector Regression) were used to predict narcissistic traits from brain structural organization and from other relevant normal and abnormal personality features. Results showed that a circuit including the lateral and middle frontal gyri, the angular gyrus, Rolandic operculum, and Heschl's gyrus successfully predicted narcissistic personality traits ($p < 0.003$). Moreover, narcissistic traits were predicted by normal (openness, agreeableness, conscientiousness) and abnormal (borderline, antisocial, insecure, addicted, negativistic, machiavellianism) personality traits. This study is the first to predict narcissistic personality traits via a supervised machine learning approach. As such, these results may expand the possibility of deriving personality traits from neural and psychological features.

ARTICLE HISTORY
Received 28 September 2022
Revised 28 June 2023
Published online 31 July 2023

KEYWORDS
Narcissism; narcissistic personality disorder; neuroimaging; Kernel Ridge Regression; support vector regression

1. Introduction

Narcissism can be conceptualized as a general dimension of personality functioning, affecting self-esteem, self-coherence, uniqueness, interpersonal affiliation, relativeness, and empathic capability (Ronningstam, 2011). However, narcissism could also result in pathological manifestations. The construct of pathological narcissism includes two subtypes: grandiose and vulnerable narcissism (Miller et al., 2011). Grandiose narcissism, also being referred to as *overt narcissism*, is characterized by a feeling of grandiosity, anger outbursts, and dominant behaviors, whereas, on the other hand, vulnerable narcissism, or *covert narcissism*, is characterized by a sense of inadequacy, incompetence, shame, and pervasive negative affect (Miller et al., 2011). If narcissistic traits are severe in their nature, a diagnosis for Narcissistic personality disorder (NPD) (DSM-III (American Psychiatric Association, 1980), can be made. The prevalence of NPD in general population is 6.2%, with a prevalence of men with respect to women (Stinson et al., 2008). NPD is a complex clinical construct (Pincus & Lukowitsky, 2010), often comorbid with other pathological manifestations such as borderline personality, substance abuse, antisocial tendencies, and anxiety. Such comormidity contributes to render a diagnosis for NPD challenging and equivocal (George & Short, 2018; Hörz-Sagstetter et al., 2018; Jauk & Kanske, 2021; Stinson et al., 2008), because clinicians, given the paucity of biological signs, only rely on self-reported/observed behaviors, thoughts and feelings (e.g., poor empathy, disregard for others, exaggerated self-esteem and so on) to determine the presence of narcissitic traits. Moreover, according to some authors, the standard DSM (Diangostic and Statistical Manual of Mental Disorders) criteria for NPD are not able to detect the complex and multifacet personality functioning that makes up this disorder (Ronningstam, 2011, 2012).

The problem with psychiatric diagnoses is widely recognized in the clinical literature (Yager et al., 2021), and affective neuroscience has been identified as an emerging field that can contribute to overcome the limitations in the diagnostic systems through the detection of neurobiological markers (Grecucci et al., 2022). As a matter of fact, neuroimaging research has shed light

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on some of the impaired brain systems in patients with personality disorders and led to a better understanding of their neurological correlates (Jauk & Kanske, 2021; Ma et al., 2016; Schmahl & Bremner, 2006), making possible the identification of neural patterns associated with narcissism (Jauk & Kanske, 2021). For example, previous neurobiological studies have highlighted the presence of gray matter (GM) abnormalities in both non-clinical individuals and NPD patients (Nenadić et al., 2021; Schulze et al., 2013). Specifically, it has been shown that pathological narcissism is characterized by anomalies in a fronto-paralimbic network including the left anterior insula, the rostral and medial cingulate cortex, as well as the dorsolateral cortex (Schulze et al., 2013). In this regard, a recent study by George and Short (2018) showed a persistent structural deficiency in the thickness of the insular cortex of individuals in the NPD group compared to the control group.

Furthermore, Scalabrini et al. (2017), by applying regions of interest and spectral analyses to thirty-two healthy male participants, showed that the left postcentral gyrus and the right anterior insula were negatively correlated with the intrinsic brain activity and that this relationship was mediated by narcissistic traits. For what concerns the white matter, Chester et al. (2016), by using Diffusion Tensor Imaging (DTI), found a link between narcissism and a structural integrity in the medial prefrontal cortex and in the ventral striatum of NPD patients. Additionally, Nenadić and colleagues found a reduced fractional anisotropy in the right frontal lobe of NPD patients (Nenadić et al., 2015). Nonetheless, one problem with the studies mentioned here is that they suffer from some methodological limitations. First, they used mass-univariate statistical techniques that treat each voxel in isolation without taking into account statistical dependencies among voxels. Second, individual differences were not taken into consideration (Baggio et al., 2023; Grecucci et al., 2022). Third, results were derived from small size samples. Due to these limitations, dishomogeneous results are indeed present in the scientific literature. Moreover, no one, to the best of our knowledge, has tried to build a model that could predict narcissistic traits from brain features and that can be also utilized to assess new unobserved cases. Results from previous studies were in fact not tested for their generalization outside the sample considered. In a future translational perspective, predicting new cases represents a benchmark for the analysis of neuroscientific results (Grecucci et al., 2022). Therefore, building predictive models holds enormous potential for improving our comprehension of how the brain might be decoded to predict psychological variables (Grecucci et al., 2022, 2023). One class of neuroimaging methods that allows the building of such models is the one based on supervised machine learning. Supervised machine learning (SML) has been increasingly used for neuroscientific research (Elhai & Montag, 2020) to predict class labels or continuous variables of interest (Hinton, 2011; Sarker, 2021). Compared to standard frequentist approaches, SML approaches, being multivariate, provide more sensitivity and flexibility (Schrouff et al., 2013), and, most importantly, results are tested for generalization to predict new cases. Moreover, generalizability is not assumed, as it is in frequentist approaches, but is instead empirically tested (Grecucci et al., 2023). Following these considerations, the first aim of this study was to build build a model that could predict narcissistic personality traits from brain structural features by using a SML method.

An intriguing question still to be answered is whether other normal and abnormal personality traits are associated with, and can be used to predict, narcissism. Recent neuroscientific studies (Jauk & Kanske, 2021; Mitra & Fluyau, 2020) have, in fact, suggested that there might be a possible relationship between narcissism and other personality dimensions. For example, individuals diagnosed with NPD have also been shown to display Antisocial traits and Machiavellinism (the tendency to lie and manipulate others; see the concept of "Dark Triad" (Jonason et al., 2009). By the same token, Allroggen et al. (2018) found that vulnerable narcissism was associated with Neuroticism and low Agreeableness (Big Five), while grandiose narcissism was associated with low Agreeableness and high Extraversion. Similarly, Zajenkowski and Szymaniak (2021) found that high vulnerable narcissism was associated with a high level of Openness. Although these studies demonstrated a correlation between narcissism and other normal and abnormal perosonality traits, it still remains unclear whether these dimensions could predict narcissism and what their relative contribution is when they are used in one single model. In other words, which are the most predictive personality traits of narcissism?

The second aim of this paper was thus to build a model that could predict narcissistic traits from normal and abnormal personality features. To detect abnormal personality traits we used the Personality Style and Disorder Inventory (PSSI), and and the Short Dark Triad (SD3). To detect normal personality traits we used the Revised Neo Personality Inventory (NEO-PI-R).

In sum, the purpose of this paper was twofold: we tried to investigate the brain features characterizing narcissistic traits and to assess the relationship between narcissism and other personality traits/dimensions. Concurrently, to overcome the limitations of previous studies, we intended to use supervised machine learning approaches to build two predictive models: one based on structural brain features, and the other based on normal and abnormal personality features.

From a neural point of view, we expected to find areas such as the left anterior insula, the rostral part of the anterior cingulate cortex, the medial cingulate cortex, bilateral medial, orbital, and dorsolateral prefrontal cortex, to predict narcissism. These regions have been separately outlined by previous studies and have been related to personality and emotional functioning (Nenadić et al., 2021; Schulze et al., 2013). From a psychological point of view, we expected that normal traits such as Neuroticism, Extraversion, Openness, and Agreeableness from the NEO-PI-R could be predictive of narcissism in line with previous observations (Zajenkowski & Szymaniak, 2021). We also expected to find abnormal personality traits such as Borderline and Antisocial traits (PSSI) to predict narcissism. Previous studies have highlighted some commonalities between narcissism and Borderline personality (in particular impulsivity and emotional dysregulation) but also between narcissism and Antisocial personality (in particular anger outburst and disrespect for the rules) (Dadomo et al., 2016, 2018; De Panfilis et al., 2019; Grecucci et al., 2022; Mattevi et al., 2019). Finally, given the fact that narcissistic personalities usually manipulate others to gain control and lie to increase their importance (Andrew et al., 2008; Heym et al., 2019; Massey-Abernathy & Byrd-Craven, 2016), we also expected that Machiavellianism (SD3) would predict narcissistic traits.

2. Method

2.1. Participants

Structural MRI and Questionnaire data were extracted from the MPI-Leipzig Mind Brain-Body dataset (OpenNeuro database, Accession Number: ds000221) (Babayan et al., 2020). The dataset includes MRI and behavioral data of 318 participants (LEMON protocol and Neuroanatomy & Connectivity Protocol) who took part in a project conducted by the Max Planck Institute (MPI) of Human Cognitive and Brain Sciences in Leipzig and authorized by the ethics committee of the University of Leipzig (154/13-ff) (Babayan et al., 2019). We selected the data of 135 healthy participants (F = 64, age = 31.94) from the Neuroanatomy & Connectivity Protocol (N&C). Eligibility for our study was based on the applicants being in good health, not under any medication, and with no history of substance abuse nor neurological diseases. Moreover, the availability of three questionnaires scores (PSSI, NEO-PI-R, SD3) was an

Table 1. Demographics and behavioral scores of participants.

Demographics	
Participants (N)	135
Age in years	31.94 ± 15.06
Gender	64 Females; 71 Males
PSSI subscales	
Narcissist	12.14 ± 4.76
Paranoid	10.04 ± 4.34
Schizoid	9.43 ± 4.64
Schizotypal	9.02 ± 4.95
Borderline	6.86 ± 4.14
Histrionic	12.92 ± 4.40
Antisocial	6.44 ± 4.41
Compulsive	16.52 ± 5.41
Insecure	11.50 ± 4.37
Addicted	12.95 ± 5.26
Negativistic	6.81 ± 4.62
Depressive	8.84 ± 4.12
Self-sacrificing	13.76 ± 4.29
Rhapsodic	15.75 ± 4.58
NEO-PI-R subscales	
Neuroticism	13.80 ± 3.27
Extraversion	19.72 ± 2.80
Openness	20.43 ± 2.94
Agreeableness	21.43 ± 2.37
Conscientiousness	20.02 ± 3.29
SD3 subscales	
Machiavellianism	20.63 ± 3.79
Narcissism	24.70 ± 4.75
Psychopathy	18.18 ± 4.24

additional essential inclusion criterion. Participants' demographic and behavioral data were reported in Table 1. The mean and standard deviation are reported for age and questionnaire's subscales.

2.2. MRI data

The MPI-Leipzig Mind Brain-Body dataset comprises quantitative T1-weighted, functional, resting state, and diffusion-weighted images acquired at the Day Clinic for Cognitive Neurology of the University Clinic Leipzig and the Max Planck Institute for Human and Cognitive and Brain Sciences (MPI CBS) in Leipzig, Germany (Babayan et al., 2019). For the purpose of our research, we considered just the T1-weighted images. Magnetic Resonance Imaging (MRI) was performed on a 3T Siemens MAGNETOM Verio scanner (Siemens Healthcare GmbH, Erlangen, Germany) with a 32-channel head coil. The MP2RAGE sequence consisted of the following parameters: sagittal acquisition orientation, one 3D volume with 176 slices, TR = 5000 ms, TE = 2.92 ms, TI1 = 700 ms, TI2 = 2500 ms, FA1 = 4°, FA2 = 5°, pre-scan normalization, echo spacing = 6.9 ms, bandwidth = 240 Hz/pixel, FOV = 256 mm, voxel size = 1 mm isotropic, GRAPPA acceleration factor 3, slice order = interleaved, duration = 8 min 22 s.

2.3. Preprocessing and machine learning analyses of brain data

We performed preprocessing on all the anatomical images through SPM12 and the Computational Anatomy Toolbox (CAT12), in the environment of MATLAB (2018). After the manual re-orientation through the anterior commissure, images were segmented into gray matter, white matter, and cerebrospinal fluid. In this study, only the gray matter was further used for the successive steps. A diffeomorphic anatomical registration exponential Lie algebra (DARTEL) (Ashburner, 2007) approach was then applied to normalize each subject's gray matter image to the average DARTEL template and to the Montreal Neurological Institute (MNI) space. Finally, a smoothing of 10 was used.

Kernel Ridge Regression (KRR), a quick and computationally efficient method for MRI parameter estimation (Nataraj et al., 2017), was used inside the PRoNTo toolbox (http://www.mlnl.cs.ucl.ac.uk/pronto/) to generate a predictive model of narcissism. The narcissist scale of PSSI was used as regression target. Previous neuroimaging studies have indicated that KRR is an accurate method for forecasting and has a high estimated prediction level (Chu et al., 2011). To build this predictive model, we included gray matter features masked with a general no-eyes mask (SPMnoeyes.nii) as suggested by PRoNTo developers. KRR with optimized hyper-parameter tuning (0.0001, 0.01, 1, 10, 100, 1000) was then applied. Five-fold nested CV was used as a cross-validation model (Schrouff et al., 2013). "Mean center features" and "normalize samples" options were additionally selected to normalize the distribution. The effect of gender was regressed out from the model to avoid confounds. The goodness of prediction (R^2), mean squared error (MSE), and their relative p values were used to evaluate the performance of the model in predicting new cases. To assess whether the obtained measures were not predicted by chance, the permutation test was used. In particular, we permuted the narcissistic values among individuals 1,000 times without replacement, repeating the cross-validation prediction process each time (Portugal et al., 2019). The Automated Anatomical Labeling (AAL) atlas consisting of 116 brain regions was used to detect the contribution of each region. Being KRR a whole brain approach, all the regions were estimated for their contribution to the statistical model. Regions were ranked in order of percentage of explained variance from the most contributing to the least contributing region. Only regions with more than 1% contribution to the statistical model are displayed and discussed.

2.4. Questionnaires

In order to investigate the anatomical correlates of narcissism, we considered the scores of the "narcissist" subscale of the PSSI, a questionnaire developed and revised by Kuhl and Kazén (2009). The PSSI is a validated self-report inventory for the measure of personality styles, and it enables a complex characterization of personality on a spectrum ranging from non-pathological personality traits to clinical personality disorders, consisting of 140 items and 14 subscales: Paranoid, Schizoid, Schizotypal, Borderline, Histrionic, Narcissist, Antisocial, Compulsive, Insecure, Addicted, Negativistic, Depressive, Self-sacrificing, Rhapsodic (Kuhl & Kazén, 2009). The PSSI is a standardized inventory that offers objective procedures and analyses and has an acceptable reliability (*Cronbach's* $\alpha = 0.64–0.79$) (Wolf et al., 2022) and an acceptable construct validity for clinical and non-clinical behavior (Kuhl & Kazén, 2009). Furthermore, we examined the association of the PSSI narcissistic score with the Short Dark Triad (SD3), a 27-item questionnaire that measures three socially aversive traits: Machiavellianism, Narcissism, and Psychopathy (Jones & Paulhus, 2014). The SD3 measure was evaluated in terms of construct, convergent, and discriminant validity, internal consistency (≥.72), and test-retest reliability (≥.73) (Malesza et al., 2019). Finally, we used the NEO-PI-R (Costa & McCrae, 2008), a scale that measures the five major personality dimensions (Five-Factor Model), with 240 items grouped into five scales: Neuroticism, Extraversion, Openness to Experience, Agreeableness, and Conscientiousness. Moreover, the NEO-PI-R has a test – retest reliability ranging from .63 to .83 (Ashton, 2013).

2.5. *Machine learning analyses on behavioral scores derived from questionnaires*

First of all, to analyze behavioral data, we applied the feature selection procedure, that produces more generalizable outcomes due to the automatic variables addition or removal at each iteration, in order to reduce dimensions (Elhai & Montag, 2020). To make a solid decision, the neighborhood component analysis (NCA) (Djerioui et al., 2019) was applied to eliminate the redundant features in our predictive model and to prevent the dimensionality curse (Bellman, 2015). Tuning the regularization parameter for feature selection, using five-fold cross-validation, usually produces the minimum regression loss (Yang et al., 2012).

Secondly, we adopted a supervised machine learning approach to analyze behavioral data. Due to its generalization capability and high predictive accuracy, we used Support Vector Regression as algorithm (Al-Anazi & Gates, 2012). Although Support Vector Machine (SVM) was mainly developed for classification, it has also been successfully applied to regression and prediction problems (Wang et al., 2014; Xingpo et al., 2021). Hyperparameter optimization by the grid search method was utilized (Elgeldawi et al., 2021). A linear kernel function was used, with a box constraint, epsilon, and Kernel scale as parameters. We used a 5-fold grid search algorithm for the parameter tuning, as previous studies have demonstrated its efficiency and reliability (Yin & Yin, 2016). The use of K-fold cross-validation protects against overfitting by partitioning the data set into folds and estimating accuracy on each fold (Where $K = 5,10$) (Gareth et al., 2013). The R^2 and MSE were selected as performance assessment metrices for forecasting the narcissistic score from behavioral data (Baecker et al., 2021).

Finally, to measure feature importance, and for an interpretable machine learning model, we applied the Shapley value function in MATLAB (2018). We used a specified query point from the average prediction at the point of interest, in order to interpret as close as possible the mean of the narcissistic score (see Table 1). Moreover, we used the fit function through Suport Vector Regression model, that indicates how much each predictor deviates from the query point (Rodríguez-Pérez & Bajorath, 2020).

3. Results

3.1. *A predictive model of narcissism based on brain features*

KRR returned a significant model able to predict narcissism traits from gray matter features ($r = 0.37$ $p = 0.001$; $R^2 = 0.14$ $p = 0.002$; $MSE = 19.62$ $p = 0.001$). The most important brain regions predicting narcissistic traits included the middle orbito-frontal area, the Rolandic operculum, the angular gyrus, the rectus, and the transverse temporal gyrus (Heschl's gyrus) (see Table 2 and Figure 1).

3.2 *A predictive model of narcissism based on personality features*

Of all the subscales of PSSI, NEO-PI-R, and SD3, only ten survived in the NCA: Borderline, Insecure, Addicted, Negativistic, and Antisocial personality traits from PSSI, Machiavellianism and Narcissism from SD3, Openness, Agreeableness, and Conscientiousness from NEO-PI-R. These features were then used to build a predictive model based on support vector regression. The model predicting narcissistic traits returned the following values: $R2 = 0.47$, $MSE = 12.08$. Upon Shapley values analysis, the predicted narcissistic score was 11.8897, with a query of 0.0729 below the average prediction of 11.9626. Openness and Narcissism had the largest positive contributions. Borderline, Antisocial, and Machiavellianism on this query had a positive contribution. The sum of Shapley values yielded the difference of actual and average prediction (0.0729). For interpretation of the Shapley values for each subscale, in order of importance: NEO_Openness = 0.815, SD3_Narcissism = 0.729, PSSI_Borderline = −0.630, PSSI_Antisocial = −0.485, SD3_Machiavellianism = −0.470, PSSI_Addicted = 0.423, NEO_Agreeableness = −0.397, PSSI_Negativistic = −0.305, PSSI_Insecure = 0.215 and NEO_Conscientiousness = 0.025. Ultimately, the subscales contributed to the prediction of the particular instance compared to the average prediction for the dataset (See Figure 2)

4. Discussion

Narcissistic personality traits are very common in both clinical and non-clinical populations. Previous studies

Table 2. Brain areas that emerged in the whole brain analysis on the narcissistic score.

ROI Label[a]	ROI weight (%)[b]	ROI size (vox)[c]	Exp. Ranking[d]
Frontal_Mid_Orb_L	2.02	1210	113.8
Rolandic_Oper_R	2.02	2946	113.2
Angular_L	1.85	2739	112
Rectus_L	1.82	1780	110.2
Heschl_R	1.8	513	107.4
Cerebelum_7b_R	1.62	692	110.6
Precentral_R	1.56	6310	105.4
Postcentral_R	1.53	6986	103.8
Angular_R	1.52	3628	101.8
Parietal_Inf_L	1.5	5610	101.2
Parietal_Inf_R	1.48	2671	101.4
Frontal_Mid_Orb_R	1.47	1583	101.6
Cerebelum_8_R	1.43	2603	100.2
Cerebelum_Crus2_R	1.42	3901	98.8
Frontal_Inf_Oper_R	1.42	2838	99
Cingulum_Ant_L	1.38	3248	99.4
Rectus_R	1.32	1571	88.8
Frontal_Sup_Orb_L	1.31	1666	91.8
Parietal_Sup_R	1.31	3557	95
Postcentral_L	1.26	8649	92.4
SupraMarginal_L	1.26	2879	90.8
SupraMarginal_R	1.25	3768	91.2
Cerebelum_7b_L	1.24	863	101.8
Frontal_Mid_R	1.21	9213	89.4
Rolandic_Oper_L	1.16	2402	88.2
Olfactory_L	1.15	671	85
Cerebelum_Crus1_R	1.15	4791	86
Cingulum_Mid_L	1.13	4478	81
Paracentral_Lobule_L	1.1	2490	82
Frontal_Mid_Orb_L	1.09	2061	77.4
Cerebelum_9_R	1.08	1320	74

Note: [a]ROI labels are derived from the 116 AAL atlas (Tzourio-Mazoyer et al., 2002).
[b]ROI weight column (in %) shows the normalized contribution of each area. This value is used to sort the table's rows in descending order. Please note that only regions whose contribution exceeded 1% are displayed.
[c]ROI size column shows the ROI size in voxels/features, providing information on the overlap between the atlas and the data.
[d]The Exp. Ranking (expected Ranking) column shows how stable the ranking of the region is across folds, and it is computed from the ranking in each fold (five-fold cross-validation).

have reported confusing results on the neural bases of narcissism probabibly due to methodological limitations. Moreover, to the best of our knowledge, no previous studies have attempted to build a predictive model of narcissistic traits starting from neural and psychological features. By using two supervised machine learning methods, we were able to build two predictive models for narcissism: one based on neural features (gray matter concentration) and the other one based on personality features. Our findings are discussed further in the following sections.

4.1. The narcissistic brain

Kernel Ridge Regression was applied to structural brain images, and the results indicated that narcissistic traits could be predicted by specific regions. Among these regions, our model reported the orbitofrontal cortex, the Rolandic operculum, the angular gyrus, the rectus, and the Heschl's gyrus as most important areas. According to the weight results, in our discussion we will consider the brain areas with a ROI weight equal or above 1.8%. In order of importance, the first region highlighted by the model was the orbitofrontal cortex, which is part of the prefrontal cortex. In previous research, the prefrontal cortex has been associated with narcissism. In particular, Mao and Mao et al. (2016) found an association between narcissism and decreased cortical volume in the right dorsolateral prefrontal cortex, right postcentral gyrus, and left medial prefrontal cortex. Furthermore, our findings are consistent with previous studies that have found alterations in the prefrontal cortex in sub-clinical narcissistic individuals (Nenadić et al., 2021). Similarly, concerning clinical narcissism, a previous study of Schulze et al. (2013) showed a GM concentration's decrease in a series of areas implicated in empathy, such as the bilateral superior frontal gyrus, dorsolateral and medial parts, the bilateral middle frontal gyrus, and the left anterior insular region, suggesting an altered empathic functioning (Schulze et al., 2013). The gyrus rectus, the fourth region identified by our model, is also part of the orbitofrontal cortex, and it

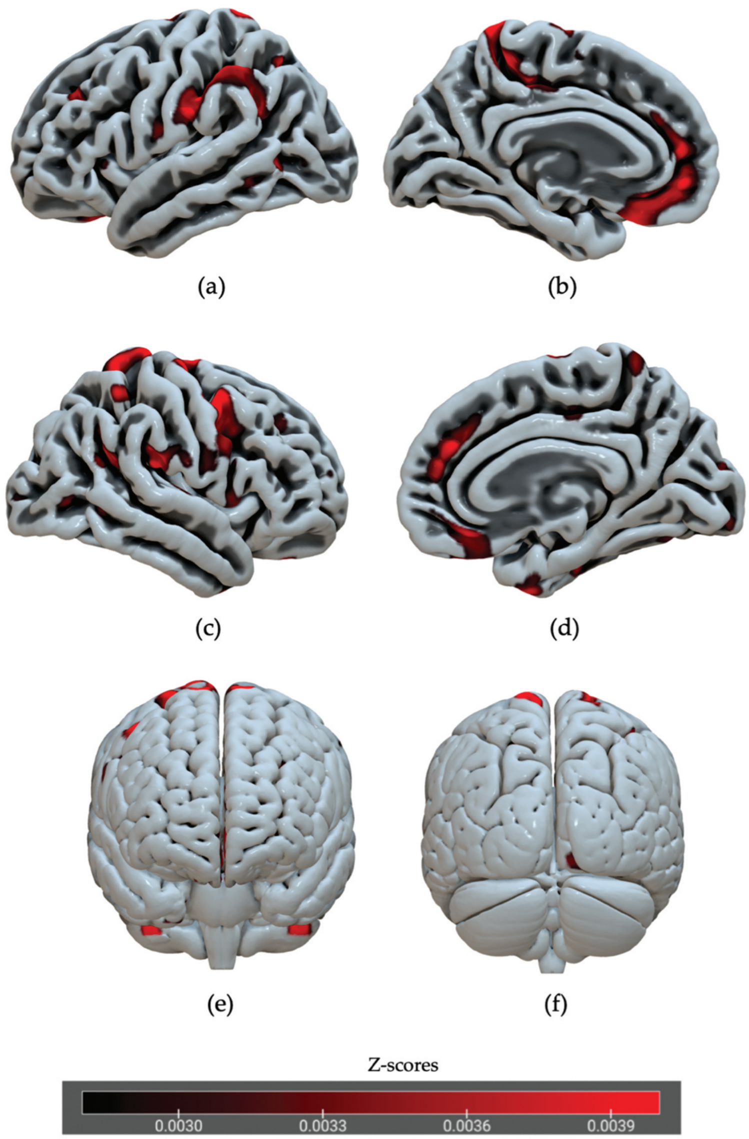

Figure 1. Neural results from the whole brain analysis on the narcissistic score. Significant regions are displayed on the MNI-ICBM152 atlas using the visualization software Surf Ice (https://www.nitrc.org/projects/surfice/). The red regions represent the highest thredshold of interest with relatively large magnitude z statistics (see the color bar). The left hemisphere is shown in (a) and (b), and the right hemisphere is shown in (c) and (d). Frontal (e) and posterior (f) views are also shown.

has been linked to cognitive processes of emotions (Li et al., 2023).

The Rolandic operculum (the second most important area in the predictive model of narcissistic traits), instead, has been associated with specific mental disorders, excluding narcissism. Indeed, Schulze and colleagues have found increased GM volume in patients with borderline personality disorder (Schulze et al., 2016) and Zhang and colleagues found decreased GM volume in addiction-related disorders (Zhang et al., 2021), two disorders that share some commonalities with NPD. Consistently, the Rolandic operculum has been shown to have a role in emotion processing. Lesions in the right Rolandic operculum have also been shown to aggravate psychological conditions, leading to apathy, depression, anxiety, and perceived stress (Sutoko et al., 2020), all symptoms that may appear in NPD patients when confronted with specific life events. As a matter of fact, emotional instability characterizes the pathological forms of narcissism, and individuals affected by this disorder are more likely to experience negative emotional states (Besser & Zeigler-Hill, 2011). Specifically, low perceived stress in grandiose narcissism has been shown to characterized mental toughness that reflects an effective coping mechanism for stressors, as opposed to what happens in vulnerable narcissism with high perceived stress (Papageorgiou et al., 2019). Furthermore, the Rolandic operculum has been demonstrated to

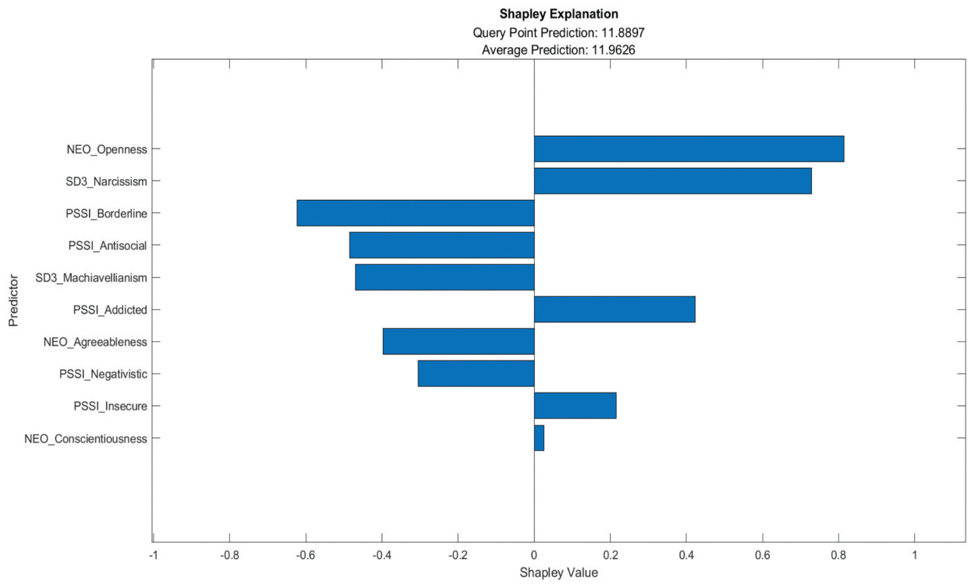

Figure 2. Shapley values with the single query point from the fit function of Support Vector Regression. The horizontal bar graph shows the Shapley values for all features, sorted by their absolute values.

contribute to bodily self-consciousness (Blefari et al., 2017). Pavanello Decaro et al. (2021) found that body image self-consciousness is linked with both vulnerable and grandiose narcissism. Higher degrees of body image self-consciousness moderate the link between vulnerable narcissistic traits and low levels of sexual functioning. On the other hand, grandiose narcissistic traits are associated with lesser body image self-consciousness and, as a result, with increased levels of sexual functioning.

The third region found in our model, in order of importance, was the angular gyrus. Although Wenjing Zhang et al. (2021) found no functional nor anatomical difference in the right angular gyrus between healthy individuals and NPD patients, we believe this region might be related to some important functions that are specifically affected in narcissistic individuals. In particular, the angular gyrus has been found to be strongly connected with the temporoparietal junction, which serves higher-level social cognitive processing such as empathy and the human ability to understand the emotional, cognitive, and mental states of others (Decety & Lamm, 2007). Confirming this link, Ruby and Decety (2004) found a relationship between the process of self/other distinction and the right angular gyrus. As such, this region may be related to abnormal self image and with self-other abnormal processes displayed by narcissists.

Lastly, the transverse temporal gyrus, also called Heschl's gyrus, also resulted to have a great importance in our predictive model of narcissism. The Heschl's gyrus is a brain area that includes the primary auditory cortex in humans and functions in response to frequency, response latency, temporal modulation, speech sensitivity, and phonemic encoding (Khalighinenjad et al., 2021). Structural abnormalities in the Heschl's gyrus have been shown to be associated with cognitive impairment in auditory perception, hallucinations, and deficits in language processing in first-episode schizophrenia (Kasai et al., 2003) and in patients with schizotypal personality disorder (SPD) (Karaali et al., 2016; Shenton et al., 2001). Recently, this area has been suggested to be linked to possible abnormal internal dialogs in Borderline Personalities (Dadomo et al., 2022; Grecucci et al., 2022). The Heschl's gyrus might also be connected to addiction-related disorders, given that a decreased GM volume has been observed in addicted individuals (Zhang et al., 2021). In this framework, meta-analytic findings have shown, both in non-clinical and clinical populations, that narcissism and psychopathy (in the Dark Triad of personality) are linked to substance-related and non-substance-related addictive behavior (Jauk & Dieterich, 2019). Additional research to clarify the role of the Heschl's gyrus in NPD and narcissistic traits is needed.

According to our expectations in the brain areas predicting narcissism, our findings included the anterior cingulate cortex, displayed in the model as Cingulum_Ant_L, the medial cingulate cortex, displayed as Cingulum_Mid_L, and prefrontal cortex areas, displayed as Frontal_Mid_Orb_L, Frontal_Mid_Orb_R, Frontal_Mid_Orb_L, Frontal_Mid_R. However, the left anterior insula is not showed as critical area of the model because its ROI weight is lower than 1%.

Previous research has shown that the anterior insula plays a critical role in emotional and cognitive empathy, suggesting that structural changes in this area could encourage self or other related empathetic processes (Li et al., 2020). Regarding empathy and its link to emotion regulation (Thompson et al., 2019), Baskin-Sommers et al. (2014) found that vulnerable narcissism was associated to patterns of low self-esteem, anger, shame, and suicidality. However, the authors also found that patients in their grandiose stage may be able to use empathic abilities when they feel in control, while at the same time they may also disengage from empathic processing (Baskin-Sommers et al., 2014).

The fact that in our study, we did not find insular regions might be related to our reduced sample size and to the analysis of narcissistic traits in non-clinical individuals. Moreover, our analysis employed a supervised machine learning algorithm, which is indeed a multivariate approach that significantly differs from the commonly used univariate approaches, being data-driven and without a priori selected brain areas.

Overall, our study highlighted the role of brain regions involved in emotion processing, social cognitive processing, and auditory perception, leading to the hypothesis of specific disruptions associated with narcissistic traits, in these domains.

4.2. The narcissistic personality

In our study, Support Vector Regression returned a predictive model of narcissistic traits based on other normal and abnormal personality traits. In particular, we found that narcissistic traits were significantly predicted by specific subscales of the NEO-PI-R, PSSI, and Dark Triad. These results will be discussed separately for each questionnaire.

For what concerns the big five dimensions (NEO-PI), we found that Openness, Agreeableness, and Conscientiousness played a role in predicting narcissism. Zajenkowski and Szymaniak (2021) recently showed that vulnerable narcissism was positively correlated with Openness but negatively correlated with Agreeableness and Extraversion. On the other hand, the authors also found that grandiose narcissism was positively correlated with Conscientiousness and negatively correlated with Agreeableness. Of note, the trait of Openness from our finding showed the highest feature importance (query point of Shapley model), coherent with Zajenkowski and Szymaniak (2021) proposal according to which narcissism and Openness share hypervigilance, enhanced awareness, and also proneness to new things and risky behaviors. Notably, in the present study, Neuroticism and Extraversion were excluded by the feature selection algorithm (NCA). This is partially consistent with previous findings showing that narcissism is not predicted by Extraversion in a regression model (Allroggen et al., 2018; Soleimani et al., 2022). Individuals with narcissistic traits are likely to use strategies derived from other personality traits to maintain a relatively positive self-image and to manage their generated emotional instability, such as Openness and Agreeableness when feeling grandiose and Agreeableness and Conscientiousness when feeling vulnerable.

For what concerns the Dark Triad, we found that Narcissism and Machiavellianism predicted the narcissistic traits. While the result on Narcissism seems obvious, the result on Machiavellianism is of particular interest. Individuals with Machiavellian traits are typically manipulative and characterized by a lack of concern, disrespect for others, and have problems to adhere to moral principles. These maladaptive features are typically displayed at varying degrees also by narcissistic personalities (Andrew et al., 2008; Heym et al., 2019; Massey-Abernathy & Byrd-Craven, 2016). Interestingly, in our analyses, Psychopathy was excluded in the feature selection process (NCA). Coherently, previous analyses have shown that Psychopathy is not predictive of narcissism (Persson et al., 2019).

Finally, we were also interested in assessing the role of other abnormal personality features in predicting narcissism. Our results showed that Borderline, Antisocial, Addicted, Negativistic, and Insecure personality traits significantly predicted the level of narcissism in our participants. In support of these findings, people with Narcissistic Personality Disorder appear in the 15% of Borderline Personality Disorder (BPD) diagnosis, sharing the same impulsivity, affective and interpersonal instability (Palmer et al., 2018). Additionally, Kernberg (1992) described people with antisocial personality disorder as essentially suffering from a severe form of NPD. Moreover, the diagnostic criteria for narcissistic and antisocial personality disorders in the DSM-5 show overlapping features such as criminality, deception, selfishness, aggressiveness, abuse, exploitation, cruelty, suspiciousness, and overconfidence (American Psychiatric Association, 2013). Several studies have reported a link between narcissism and certain addictive behaviors, as NPD patients are usually deficient in self-control (Larson et al., 2015). NPD prevalence is estimated to be 15.2% among individuals with substance use disorders such as alcohol, drug, and nicotine dependency (Stinson et al., 2008). Research has also confirmed a relationship between narcissistic pathology's distorted self-image and the employment of externalizing coping strategies (Kealy et al., 2017). Furthermore, Passive-Aggressive (Negativistic) Personality Disorder (PAPD) has been shown to share features with NPD such as grandiosity and interpersonal exploitation characteristics, which represent the most predictive NPD criteria for PAPD diagnosis (Fossati et al., 2000). Additionally, Fossati et al. (2000) suggested that DSM-IV PAPD should be considered as a subtype of narcissistic disorder. Lastly, insecure individuals seem to develop what is considered to be narcissism in its purest form, namely vulnerable narcissism, a type of narcissism that is connected to self-elevating behavior to alleviate the anguish and shame caused by self-doubt (Kowalchyk et al., 2021).

5. Conclusions

In this study, supervised machine learning (KRR) was used for the first time to test the hypothesis that individual differences in narcissistic personality traits could be predicted from specific structural brain features. We were able to provide evidence that narcissism is related to the structural properties of specific brain regions. The statistical model that was generated, if appropriately integrated with other biological, social, and cultural variables, could be used one day to predict narcissistic traits. Therefore, this study extends the results of previous research, which has largely used univariate approaches and has not provided a predictive model. Moreover, a supervised machine learning approach (SVR) was also used to test the hypothesis that individual differences in narcissistic personality traits could be predicted from other normal (Big Five) and abnormal (Dark Triad, Personality Style, and Disorder Inventory) personality traits. These results shed further light on the link between personality disorders and normal personality traits.

6. Limitations

This study does not come without limitations. Our results are limited to gray matter features as white matter features or functional activity were not investigated. Future studies may want to explore this issue. Additionally, although the number of participants recruited in the present study was larger as compared to previous studies, a future direction might be to include an even larger sample size for brain-wide association analyses (Marek et al., 2022). A further limitation relates to the measurement of narcissistic traits. In our study, we measured narcissism using the PSSI, which does not clearly differentiate between the vulnerable and grandiose subtypes, although the items seem to be much more related to the grandiose side of narcissism. Future studies may want to explore more in depth this issue and find possible differences between the two types of narcissism. Furthermore, the trait scores measured in this study (via the PSSI) were bound to the construct measured by the questionnaire itself. As such, the trait we measured is affected by the theory and reliability of the questionnaire used. Lastly, our predictive model is limited to one biological measure (GM concentration) and to a few psychological variables (the questionnaires considered). Future studies are needed to improve this predictive model by adding other biological, genetic, social, psychological, and cultural variables.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

The author(s) reported there is no funding associated with the work featured in this article.

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Data availability statement

The dataset analyzed during the current study is available in the MPI-Leipzig_Mind-Brain-Body repository, https://openneuro.org/datasets/ds000221/versions/1.0.0 (accessed on 1 April 2022). The complete LEMON Data can be accessed via Gesellschaft für wissenschaftliche Datenverarbeitung mbH Göttingen (GWDG) https://www.gwdg.de/ (accessed on 1 April 2022). Raw and preprocessed data at this location is accessible through web browser https://ftp.gwdg.de/pub/misc/MPI-Leipzig_Mind-Brain-Body-LEMON/ (accessed on 1 December 2021) and a fast FTP connection (https://ftp.gwdg.de/pub/misc/MPI-Leipzig_Mind-Brain-Body-LEMON/ (accessed on 1 April 2022)). The feature-selection code that was used in the second analysis of machine learning method can be accessed in the following repository: https://github.com/lokbaimai/narcissism/.

References

Al-Anazi, A. F., & Gates, I. D. (2012). Support vector regression to predict porosity and permeability: Effect of sample size. *Computers & Geosciences*, *39*, 64–76. https://doi.org/10.1016/j.cageo.2011.06.011

Allroggen, M., Rehmann, P., Schürch, E., Morf, C. C., & Kölch, M. (2018). The relationship between narcissism and personality traits of the five-factor-model in adolescents and young adults. *Zeitschrift für Kinder- und Jugendpsychiatrie und Psychotherapie*, *46*(6), 516–522. https://doi.org/10.1024/1422-4917/a000588

American Psychiatric Association. (1980). *Diagnostic and statistical manual of mental disorders* (3rd ed.).

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders: DSM-5* (Vol. 5). https://doi.org/10.1176/appi.books.9780890425596

Andrew, J., Cooke, M., & Muncer, S. J. (2008). The relationship between empathy and machiavellianism: An alternative to empathizing–systemizing theory. *Personality and Individual Differences*, *44*(5), 1203–1211. https://doi.org/10.1016/j.paid.2007.11.014

Ashburner, J. (2007). A fast diffeomorphic image registration algorithm. *NeuroImage*, *38*(1), 95–113. https://doi.org/10.1016/j.neuroimage.2007.07.007

Ashton, M. C. (2013). Personality traits and the inventories that measure them. In *Individual differences and personality* (2nd ed., pp. 27–55). Academic Press, Elsevier Inc. https://doi.org/10.1016/B978-0-12-416009-5.00002-5

Babayan, A., Baczkowski, B., Cozatl, R., Dreyer, M., Engen, H., Erbey, M., Falkiewicz, M., Farrugia, N., Gaebler, M., Golchert, J., Golz, L., Gorgolewski, K., Haueis, P., Huntenburg, J., Jost, R., Kramarenko, Y., Krause, S., Kumral, D., Lauckner, M., . . . Villringer, A. (2020). *MPI-Leipzig _Mind-Brain-Body*. OpenNeuro. https://doi.org/10.18112/openneuro.ds000221.v1.0.0

Babayan, A., Erbey, M., Kumral, D., Reinelt, J., Reiter, A., Röbbig, J., Schaare, H., Uhlig, M., Anwander, A., & Bazin, P. (2019). A mind-brain-body dataset of MRI, EEG, cognition, emotion, and peripheral physiology in young and old adults. *Scientific Data*, *6*(1), 180308. https://doi.org/10.1038/sdata.2018.308

Baecker, L., Dafflon, J., Da Costa, P. F., Garcia-Dias, R., Vieira, S., Scarpazza, C., Calhoun, V. D., Sato, J. R., Mechelli, A., & Pinaya, W. H. (2021). Brain age prediction: A comparison between machine learning models using region-and voxel-based morphometric data. *Human Brain Mapping*, *42*(8), 2332–2346. https://doi.org/10.1002/hbm.25368

Baggio, T., Grecucci, A., Meconi, F., & Messina, I. (2023). Anxious Brains: A Combined Data Fusion Machine Learning Approach to Predict Trait Anxiety from Morphometric Features. *Sensors*, *23*(2), 610. https://doi.org/10.3390/s23020610

Baskin-Sommers, A., Krusemark, E., & Ronningstam, E. (2014). Empathy in narcissistic personality disorder: From clinical and empirical perspectives. *Personality Disorders*, *5*(3), 323–333. https://doi.org/10.1037/per0000061

Bellman, R. E. (2015). *Adaptive Control Processes: A Guided Tour*. Princeton University Press.

Besser, A., & Zeigler-Hill, V. (2011). Pathological forms of narcissism and perceived stress during the transition to the university: The mediating role of humor styles. *International Journal of Stress Management*, *18*(3), 197. https://doi.org/10.1037/a0024826

Blefari, M. L., Martuzzi, R., Salomon, R., Bello-Ruiz, J., Herbelin, B., Serino, A., Blanke, O., & Foxe, J. (2017). Bilateral Rolandic operculum processing underlying heartbeat awareness reflects changes in bodily self-consciousness. *European Journal of Neuroscience*, *45*(10), 1300–1312. https://doi.org/10.1111/ejn.13567

Chester, D. S., Lynam, D. R., Powell, D. K., & DeWall, C. N. (2016). Narcissism is associated with weakened frontostriatal connectivity: A DTI study. *Social Cognitive and Affective Neuroscience*, *11*(7), 1036–1040. https://doi.org/10.1093/scan/nsv069

Chu, C., Ni, Y., Tan, G., Saunders, C. J., & Ashburner, J. (2011). Kernel regression for fMRI pattern prediction. *NeuroImage*, *56*(2), 662–673. https://doi.org/10.1016/j.neuroimage.2010.03.058

Costa, P. T., Jr., & McCrae, R. R. (2008). *The revised neo personality inventory (neo-pi-r)*. Sage Publications, Inc. https://doi.org/10.4135/9781849200479.n9

Dadomo, H., Grecucci, A., Giardini, I., Ugolini, E., Carmelita, A., & Panzeri, M. (2016). Schema Therapy for Emotional Dysregulation: Theoretical Implication and Clinical Applications. *Frontiers in Psychology*, *7*. https://doi.org/10.3389/fpsyg.2016.01987

Dadomo, H., Panzeri, M., Caponcello, D., Carmelita, A., & Grecucci, A. (2018). Schema therapy for emotional dysregulation in personality disorders: A review. *Current Opinion in Psychiatry*, *31*(1), 43–49. https://doi.org/10.1097/yco.0000000000000380

Dadomo, H., Salvato, G., Lapomarda, G., Ciftci, Z., Messina, I., & Grecucci, A. (2022). Structural Features Predict Sexual Trauma and Interpersonal Problems in Borderline Personality Disorder but Not in Controls: A Multi-Voxel Pattern Analysis. *Frontiers in Human Neuroscience*, *16*. https://doi.org/10.3389/fnhum.2022.773593

Decety, J., & Lamm, C. (2007). The role of the right temporoparietal junction in social interaction: How low-level computational processes contribute to meta-cognition. *The Neuroscientist*, *13*(6), 580–593. https://doi.org/10.1177/1073858407304654

De Panfilis, C., Antonucci, C., Meehan, K. B., Cain, N. M., Soliani, A., Marchesi, C., & Sambataro, F. (2019). Facial emotion recognition and social-cognitive correlates of narcissistic features. *Journal of Personality Disorders*, *33*(4), 433–449. https://doi.org/10.1521/pedi_2018_32_350

Djerioui, M., Brik, Y., Ladjal, M., & Attallah, B. (2019). Neighborhood component analysis and support vector machines for heart disease prediction. *Ingénierie des Systèmes d'Information*, *24*(6), 591–595. https://doi.org/10.18280/isi.240605

Elgeldawi, E., Sayed, A., Galal, A. R., & Zaki, A. M. (2021). Hyperparameter tuning for machine learning algorithms used for Arabic sentiment analysis. *Informatics*, *8*(4), 79. https://doi.org/10.3390/informatics8040079

Elhai, J. D., & Montag, C. (2020). The compatibility of theoretical frameworks with machine learning analyses in psychological research. *Current Opinion in Psychology*, *36*, 83–88. https://doi.org/10.1016/j.copsyc.2020.05.002

Fossati, A., Maffei, C., Bagnato, M., Donati, D., Donini, M., Fiorilli, M., & Novella, L. (2000). A psychometric study of DSM-IV passive-aggressive (negativistic) personality disorder criteria. *Journal of Personality Disorders*, *14*(1), 72–83. https://doi.org/10.1521/pedi.2000.14.1.72

Gareth, J., Daniela, W., Trevor, H., & Robert, T. (2013). *An introduction to statistical learning: With applications in R*. Spinger.

George, F. R., & Short, D. (2018). The cognitive neuroscience of narcissism. *Journal of Brain, Behavior and Cognitive Sciences*, *1*, ID 6. https://www.imedpub.com/articles/the-cognitive-neuroscience-of-narcissism.php?aid=22149

Grecucci, A., Lapomarda, G., Messina, I., Monachesi, B., Sorella, S., & Siugzdaite, R. (2022). Structural features related to affective instability correctly classify patients with borderline personality disorder. A supervised machine learning approach. *Frontiers in Psychiatry*, *13*, 804440–804440. https://doi.org/10.3389/fpsyt.2022.804440

Grecucci, A., Sorella, S., & Consolini, J. (2023). Decoding individual differences in expressing and suppressing anger from structural brain networks: A supervised machine learning approach. *Behavioural Brain Research*, *439*, 114245. https://doi.org/10.1016/j.bbr.2022.114245

Heym, N., Firth, J., Kibowski, F., Sumich, A., Egan, V., & Bloxsom, C. A. J. (2019). Empathy at the heart of darkness: Empathy deficits that bind the dark triad and those that mediate indirect relational aggression [original research]. *Frontiers in Psychiatry*, *10*. https://doi.org/10.3389/fpsyt.2019.00095

Hinton, G. E. (2011). Machine learning for neuroscience. *Neural Systems & Circuits*, *1*(1), 12. https://doi.org/10.1186/2042-1001-1-12

Hörz-Sagstetter, S., Diamond, D., Clarkin, J. F., Levy, K. N., Rentrop, M., Fischer-Kern, M., Cain, N. M., & Doering, S. (2018). Clinical characteristics of comorbid narcissistic personality disorder in patients with borderline personality disorder. *Journal of Personality Disorders*, *32*(4), 562–575. https://doi.org/10.1521/pedi_2017_31_306

Jauk, E., & Dieterich, R. (2019). Addiction and the dark triad of personality [Mini review]. *Frontiers in Psychiatry*, *10*. https://doi.org/10.3389/fpsyt.2019.00662

Jauk, E., & Kanske, P. (2021). Can neuroscience help to understand narcissism? A systematic review of an emerging field. *Personality Neuroscience*, *4*. https://doi.org/10.1017/pen.2021.1

Jonason, P. K., Li, N. P., Webster, G. D., & Schmitt, D. P. (2009). The dark triad: Facilitating a short-term mating strategy in men. *European Journal of Personality*, *23*(1), 5–18. https://doi.org/10.1002/per.698

Jones, D. N., & Paulhus, D. L. (2014). Introducing the short dark triad (SD3) a brief measure of dark personality traits. *Assessment*, *21*(1), 28–41. https://doi.org/10.1177/1073191113514105

Karaali, K., Aytaç, G., Şenol, U., & Sindel, M. (2016). Heschl's transverse gyri: Anatomy and morphological variations. *Akdeniz Tıp Dergisi*, *2*(3), 149–152. https://doi.org/10.17954/amj.2016.59

Kasai, K., Shenton, M. E., Salisbury, D. F., Hirayasu, Y., Onitsuka, T., Spencer, M. H., Yurgelun-Todd, D. A., Kikinis, R., Jolesz, F. A., & McCarley, R. W. (2003). Progressive decrease of left heschl gyrus and planum temporale gray matter volume in first-episode schizophrenia: A longitudinal magnetic resonance imaging study. *Archives of General Psychiatry*, *60*(8), 766–775. https://doi.org/10.1001/archpsyc.60.8.766

Kealy, D., Ogrodniczuk, J. S., Rice, S. M., & Oliffe, J. L. (2017). Pathological narcissism and maladaptive self-regulatory behaviours in a nationally representative sample of Canadian men. *Psychiatry Research*, *256*, 156–161. https://doi.org/10.1016/j.psychres.2017.06.009

Kernberg, O. F. (1992). *Aggression in personality disorders and perversions*. Yale University Press.

Khalighinejad, B., Patel, P., Herrero, J. L., Bickel, S., Mehta, A. D., & Mesgarani, N. (2021). Functional characterization of human Heschl's gyrus in response to natural speech. *NeuroImage*, *235*, 118003. https://doi.org/10.1016/j.neuroimage.2021.118003

Kowalchyk, M., Palmieri, H., Conte, E., & Wallisch, P. (2021). Narcissism through the lens of performative self-elevation. *Personality and Individual Differences*, *177*, 110780. https://doi.org/10.1016/j.paid.2021.110780

Kuhl, J., & Kazén, M. (2009). *PSSI: Persönlichkeits-Stil-und Störungs-Inventar*. Hogrefe.

Larson, M., Vaughn, M. G., Salas-Wright, C. P., & Delisi, M. (2015). Narcissism, low self-control, and violence among a nationally representative sample. *Criminal Justice and Behavior*, *42*(6), 644–661. https://doi.org/10.1177/0093854814553097

Li, W., Lou, W., Zhang, W., Tong, R. K., Jin, R., & Peng, W. (2023). Gyrus rectus asymmetry predicts trait alexithymia, cognitive empathy, and social function in neurotypical adults. *Cerebral Cortex (New York, N.Y. : 1991)*, *33*(5), 1941–1954. https://doi.org/10.1093/cercor/bhac184

Li, Y., Zhang, T., Li, W., Zhang, J., Jin, Z., & Li, L. (2020, March). Linking brain structure and activation in anterior insula cortex to explain the trait empathy for pain. *Human Brain Mapping*, *41*(4), 1030–1042. https://doi.org/10.1002/hbm.24858

Ma, G., Fan, H., Shen, C., & Wang, W. (2016). Genetic and neuroimaging features of personality disorders: State of the art. *Neuroscience Bulletin*, *32*(3), 286–306. https://doi.org/10.1007/s12264-016-0027-8

Malesza, M., Ostaszewski, P., Büchner, S., & Kaczmarek, M. C. (2019). The adaptation of the short dark triad personality measure – psychometric properties of a German sample. *Current Psychology*, *38*(3), 855–864. https://doi.org/10.1007/s12144-017-9662-0

Mao, Y., Sang, N., Wang, Y., Hou, X., Huang, H., Wei, D., Zhang, J., & Qiu, J. (2016). Reduced frontal cortex thickness and cortical volume associated with pathological narcissism. *Neuroscience*, *328*, 50–57. https://doi.org/10.1016/j.neuroscience.2016.04.025

Marek, S., Tervo-Clemmens, B., Calabro, F. J., Montez, D. F., Kay, B. P., Hatoum, A. S., Donohue, M. R., Foran, W., Miller, R. L., Hendrickson, T. J., Malone, S. M., Kandala, S., Feczko, E., Miranda-Dominguez, O., Graham, A. M., Earl, E. A., Perrone, A. J., Cordova, M. . . . Dosenbach, N. U. F. (2022). Reproducible brain-wide association studies require thousands of individuals. *Nature*, *603*(7902), 654–660. https://doi.org/10.1038/s41586-022-04492-9

Massey-Abernathy, A., & Byrd-Craven, J. (2016). Seeing but not feeling: Machiavellian traits in relation to physiological empathetic responding and life experiences. *Adaptive Human Behavior and Physiology*, *2*(3), 252–266. https://doi.org/10.1007/s40750-016-0041-0

MATLAB. (2018). *9.4. 0 (R2018a)*. MathWorks Inc.

Mattevi, A., Sorella, S., Vellani, V., Job, R., & Grecucci, A. (2019). Regolare la rabbia: Quale strategia? Uno studio preliminare. [Which strategy for anger regulation? A preliminary investigation of reappraisal and suppression.]. *Giornale Italiano di Psicologia*, *46*(4), 997–1010.

Miller, J. D., Hoffman, B. J., Gaughan, E. T., Gentile, B., Maples, J., & Keith Campbell, W. (2011). Grandiose and vulnerable narcissism: A nomological network analysis. *Journal of Personality*, *79*(5), 1013–1042. https://doi.org/10.1111/j.1467-6494.2010.00711.x

Mitra, P., & Fluyau, D. (2020). *Narcissistic personality disorder*. StatPearls Publishing.

Nataraj, G., Nielsen, J.-F., & Fessler, J. A. (2017). Dictionary-free MRI parameter estimation via Kernel Ridge Regression. In *2017 IEEE 14th International Symposium on Biomedical Imaging (ISBI 2017)*, Melbourne, Australia. https://doi.org/10.1109/ISBI39448.2017

Nenadic, I., Güllmar, D., Dietzek, M., Langbein, K., Steinke, J., & Gaser, C. (2015). Brain structure in narcissistic personality disorder: A VBM and DTI pilot study. *Psychiatry Research: Neuroimaging*, *231*(2), 184–186. https://doi.org/10.1016/j.pscychresns.2014.11.001

Nenadić, I., Lorenz, C., & Gaser, C. (2021). Narcissistic personality traits and prefrontal brain structure. *Scientific Reports*, *11*(1), 15707. https://doi.org/10.1038/s41598-021-94920-z

Palmer, B., & Unruh, B., Palmer, B., Unruh, B. (2018). *Borderline personality disorder: A case-based approach*. Springer International Publishing. https://doi.org/10.1007/978-3-319-90743-7

Papageorgiou, K. A., Gianniou, F.-M., Wilson, P., Moneta, G. B., Bilello, D., & Clough, P. J. (2019). The bright side of dark: Exploring the positive effect of narcissism on perceived stress through mental toughness. *Personality and Individual Differences*, *139*, 116–124. https://doi.org/10.1016/j.paid.2018.11.004

Pavanello Decaro, S., DiSarno, M., Anzani, A., DiPierro, R., & Prunas, A. (2021). Narcissistic personality traits and sexual dysfunction in women: The role of body image self-consciousness. *The Journal of Sexual Medicine*, *18*(11), 1891–1898. https://doi.org/10.1016/j.jsxm.2021.08.007

Persson, B. N., Kajonius, P. J., & Garcia, D. (2019). Revisiting the structure of the short dark triad. *Assessment*, *26*(1), 3–16. https://doi.org/10.1177/1073191117701192

Pincus, A. L., & Lukowitsky, M. R. (2010). Pathological narcissism and narcissistic personality disorder. *Annual Review of Clinical Psychology*, *6*(1), 421–446. https://doi.org/10.1146/annurev.clinpsy.121208.131215

Portugal, L. C., Schrouff, J., Stiffler, R., Bertocci, M., Bebko, G., Chase, H., Lockovitch, J., Aslam, H., Graur, S., Greenberg, T., Pereira, M., Oliveira, L., Phillips, M., & Mourão-Miranda, J. (2019). Predicting anxiety from wholebrain activity patterns to emotional faces in young adults: A machine learning approach. *NeuroImage: Clinical*, *23*, 101813. https://doi.org/10.1016/j.nicl.2019.101813

Rodríguez-Pérez, R., & Bajorath, J. (2020). Interpretation of compound activity predictions from complex machine learning models using local approximations and shapley values. *Journal of Medicinal Chemistry*, *63*(16), 8761–8777. https://doi.org/10.1021/acs.jmedchem.9b01101

Ronningstam, E. (2011). Narcissistic personality disorder in DSM-V–in support of retaining a significant diagnosis. *Journal of Personality Disorders*, *25*(2), 248. https://doi.org/10.1521/pedi.2011.25.2.248

Ronningstam, E. (2012). Alliance building and narcissistic personality disorder. *Journal of Clinical Psychology*, *68*(8), 943–953. https://doi.org/10.1002/jclp.21898

Ruby, P., & Decety, J. (2004). How would you feel versus how do you think she would feel? A neuroimaging study of perspective-taking with social emotions. *Journal of Cognitive Neuroscience*, *16*(6), 988–999. https://doi.org/10.1162/0898929041502661

Sarker, I. H. (2021). Machine learning: Algorithms, real-world applications and research directions. *SN Computer Science*, *2*(3), 160. https://doi.org/10.1007/s42979-021-00592-x

Scalabrini, A., Huang, Z., Mucci, C., Perrucci, M. G., Ferretti, A., Fossati, A., Romani, G. L., Northoff, G., & Ebisch, S. J. H. (2017). How spontaneous brain activity and narcissistic features shape social interaction. *Scientific Reports*, *7*(1), 9986–9986. https://doi.org/10.1038/s41598-017-10389-9

Schmahl, C., & Bremner, J. D. (2006). Neuroimaging in borderline personality disorder. *Journal of Psychiatric Research*, *40*(5), 419–427. https://doi.org/10.1016/j.jpsychires.2005.08.011

Schrouff, J., Rosa, M. J., Rondina, J. M., Marquand, A. F., Chu, C., Ashburner, J., Phillips, C., Richiardi, J., & Mourão-Miranda, J. (2013). PRoNTo: Pattern recognition for neuroimaging toolbox. *Neuroinformatics*, *11*(3), 319–337. https://doi.org/10.1007/s12021-013-9178-1

Schulze, L., Dziobek, I., Vater, A., Heekeren, H. R., Bajbouj, M., Renneberg, B., Heuser, I., & Roepke, S. (2013). Gray matter abnormalities in patients with narcissistic personality disorder. *Journal of Psychiatric Research*, *47*(10), 1363–1369. https://doi.org/10.1016/j.jpsychires.2013.05.017

Schulze, L., Schmahl, C., & Niedtfeld, I. (2016). Neural Correlates of Disturbed Emotion Processing in Borderline Personality Disorder: A Multimodal Meta-Analysis. *Biological Psychiatry*, *79*(2), 97–106. https://doi.org/10.1016/j.biopsych.2015.03.027

Shenton, M. E., Dickey, C. C., Frumin, M., & McCarley, R. W. (2001). A review of MRI findings in schizophrenia. *Schizophrenia Research*, *49*(1–2), 1–52. https://doi.org/10.1016/s0920-9964(01)00163-3

Soleimani, M., Pincus, A. L., Alizadeh, H., Mohammadi, A., Nokani, M., Paast, N., Qaderi Bagajan, K., & Tahmasbi, N. (2022). Five-factor model trait profiles of narcissistic grandiosity and narcissistic vulnerability in Iranian university students. *International Journal of Psychology*, *57*(3), 393–400. https://doi.org/10.1002/ijop.12833

Stinson, F. S., Dawson, D. A., Goldstein, R. B., Chou, S. P., Huang, B., Smith, S. M., Ruan, W. J., Pulay, A. J., Saha, T. D., Pickering, R. P., & Grant, B. F. (2008). Prevalence, correlates, disability, and comorbidity of DSM-IV narcissistic personality disorder: Results from the wave 2 national epidemiologic survey on alcohol and related conditions. *The Journal of Clinical Psychiatry*, *69*(7), 1033–1045. https://doi.org/10.4088/jcp.v69n0701

Sutoko, S., Atsumori, H., Obata, A., Funane, T., Kandori, A., Shimonaga, K., & Tsuji, T. (2020). Lesions in the right Rolandic operculum are associated with self-rating affective and apathetic depressive symptoms for post-stroke patients. *Scientific Reports*, *10*(1), 20264. https://doi.org/10.1038/s41598-020-77136-5

Thompson, N. M., Uusberg, A., Gross, J. J., & Chakrabarti, B. (2019). Chapter 12 - Empathy and emotion regulation: An integrative account. In N. Srinivasan (Ed.), *Progress in brain research* (Vol. 247, pp. 273–304). Elsevier. https://doi.org/10.1016/bs.pbr.2019.03.024

Tzourio-Mazoyer, N., Landeau, B., Papathanassiou, D., Crivello, F., Etard, O., Delcroix, N., Mazoyer, B., & Joliot, M. (2002). Automated anatomical labeling of activations in SPM using a macroscopic anatomical parcellation of the MNI MRI single-subject brain. *NeuroImage*, *15*(1), 273–289. https://doi.org/10.1006/nimg.2001.0978

Wang, X., Wen, J., Zhang, Y., & Wang, Y. (2014). Real estate price forecasting based on SVM optimized by PSO. *Optik*, *125*(3), 1439–1443. https://doi.org/10.1016/j.ijleo.2013.09.017

Wolf, T. G., Speyer, V. F. S., & Peter, B. (2022). "How obsessive are dentists?"––A personality styles & disorder inventory based prospective, controlled study. *Journal of Dentistry*, *124*, 104217. https://doi.org/10.1016/j.jdent.2022.104217

Xingpo, L., Muzi, L., Yaozhi, C., Jue, T., & Jinyan, G. (2021). A comprehensive framework for HSPF hydrological parameter sensitivity, optimization and uncertainty evaluation based on SVM surrogate model-A case study in Qinglong River watershed, China. *Environmental Modelling & Software*, *143*, 105126. https://doi.org/10.1016/j.envsoft.2021.105126

Yager, J., Dubovsky, S. L., & Roy-Byrne, P. P. (2021). Keeping up with the psychiatric literature: A survival guide. *Psychotherapy and Psychosomatics*, *90*(6), 359–364. https://doi.org/10.1159/000517867

Yang, W., Wang, K., & Zuo, W. (2012). Neighborhood component feature selection for high-dimensional data. *Journal of Computers*, *7*(1), 161–168. https://doi.org/10.4304/jcp.7.1.161-168

Yin, S., & Yin, J. (2016). Tuning kernel parameters for SVM based on expected square distance ratio. *Information Sciences*, *370*, 92–102. https://doi.org/10.1016/j.ins.2016.07.047

Zajenkowski, M., & Szymaniak, K. (2021). Narcissism between facets and domains. The relationships between two types of narcissism and aspects of the big five. *Current Psychology*, *40*(5), 2112–2121. https://doi.org/10.1007/s12144-019-0147-1

Zhang, M., Gao, X., Yang, Z., Wen, M., Huang, H., Zheng, R., Wang, W., Wei, Y., Cheng, J., Han, S., & Zhang, Y. (2021). Shared gray matter alterations in subtypes of addiction: A voxel-wise meta-analysis. *Psychopharmacology*, *238*(9), 2365–2379. https://doi.org/10.1007/s00213-021-05920-w