



## The many faces of dark personalities: An examination of the Dark Triad structure using psychometric network analysis

Tayler E. Truhan <sup>a,\*</sup>, Paul Wilson <sup>a</sup>, René Möttus <sup>b,c</sup>, Kostas A. Papageorgiou <sup>a,d</sup>

<sup>a</sup> Queen's University of Belfast, School of Psychology, Belfast, United Kingdom

<sup>b</sup> University of Edinburgh, Department of Psychology, Edinburgh, United Kingdom

<sup>c</sup> University of Tartu, Institute of Psychology, Tartu, Estonia

<sup>d</sup> Tomsk State University, Department of Psychology, Tomsk, Russia



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### ABSTRACT

Although the Dark Triad (DT) of personality has been studied for almost two decades, research regarding its structure is lacking, which is pertinent to understanding personality-outcome associations. This study examined the structure of the DT domains, both independently and as a cluster. Initial results were replicated with a validation sample. Participants (Study 1:  $N = 301$ ; Study 2:  $N = 224$ ) completed six self-report questionnaires that assess DT domains. Exploratory Graph Analysis (EGA) was used in a two-step process to identify lower order facets and higher order factors of the DT. EGAs suggested eight facets of Narcissism, six facets of Psychopathy, four facets of Machiavellianism, and four DT factors, as grandiose and vulnerable narcissism formed two separate factors. Network analyses highlighted the central role that Antagonism occupied in the DT network. This study provides support for the feasibility of EGA, especially with traits that may be highly correlated, such as personality components. Results highlight the multidimensionality of the DT domains that existing personality measures fail to comprehensively capture, and the need for further research to refine measurement of the DT domains and Machiavellianism in particular.

### 1. Introduction

The Dark Triad (DT) of personality includes traits from domains of subclinical psychopathy, subclinical narcissism, and Machiavellianism (Paulhus & Williams, 2002). While much of the research to date on the DT has focused on definitions and psychosocial correlates (for a review see Muris et al., 2017), there has been a lack of studies that have examined the independent and collective structure of the DT domains – that is, how their constituent traits, facets or items relate to one another.

#### 1.1. Structure and measures of the Dark Triad

Findings from available studies concerning the DT structure highlight the dynamic nature of this personality cluster, suggesting that, similar to the Big Five traits, the DT may act as three broad trait domains encompassing numerous facets (Marcus & Zeigler-Hill, 2015; Rogoza & Cieciuch, 2018). Various research, presented below, indicates that narcissism has two to three factors and seven to fifteen facets; psychopathy has two to four factors and five to seven facets;

Machiavellianism has one to five factors and three to thirteen facets; and the DT has two to three factors and up to twelve facets.

A two-dimensional structure of narcissism was first identified by Wink (1991), who proposed that narcissism could be either grandiose or vulnerable. Grandiose narcissism is characterized by exhibitionism, entitlement, and interpersonal dominance; whereas vulnerable narcissism is characterized by a fragile self-esteem, need for admiration, and shame (Miller, Lynam, et al., 2017). Recently, the Five-Factor Narcissism Inventory (FFNI; Glover et al., 2012) was developed to account for the complexities around assessing narcissism at the subclinical level. The FFNI is one of the few measures that captures both grandiose and vulnerable narcissism. For example, the Narcissistic Personality Inventory (NPI; Raskin & Hall, 1979), one of the most widely used assessments of narcissism, captures only the grandiose side. Furthermore, the factor structure of the NPI has continuously been called into question (Ackerman et al., 2011; Corry et al., 2008). The lack of distinction between vulnerable and grandiose narcissism in much of the current research limits our understanding of how narcissism operates within the personality sphere (Miller et al., 2011; Miller, Lynam, et al., 2017),

\* Corresponding author at: School of Psychology, Queen's University Belfast, David Keir Building, 18-30, Malone Road, Belfast BT9 5BN, United Kingdom.  
E-mail address: [ttruhan01@qub.ac.uk](mailto:ttruhan01@qub.ac.uk) (T.E. Truhan).

indicating that measurements of global narcissism may be redundant.

It has been suggested that the primary connection between the two opposing sides of narcissism is the tendency to react in an antagonistic manner (Miller et al., 2011). Factor analyses of the FFNI returned three higher order factors of narcissism: Antagonism, Extraversion, and Neuroticism (Miller et al., 2016). Another three dimensional model is the Narcissism Spectrum Model (Krizan & Herlache, 2018), which posits self-centered antagonism as the core feature of narcissism, framed by grandiosity on one end and vulnerability on the other. A comprehensive examination of an item pool drawn from twelve narcissism measures indicated that narcissism may be best considered in terms of at least three factors (Crowe et al., 2019): Agentic Extraversion (e.g. assertiveness, exhibitionism), Self-centered Antagonism (e.g. exploitation, entitlement), and Narcissistic Neuroticism (e.g. need for admiration, shame).

Network analyses of psychopathy items conducted with U.S. and Dutch samples indicated that callousness/lack of empathy, manipulation, and lack of guilt showed high centrality in all sample groups, suggesting these are the most prominent characteristics of this domain (Verschueren et al., 2018). The Self-Report Psychopathy Scale – Fourth Edition (SRP-4; Paulhus et al., 2016), the most recent version of the SRP, measures four aspects of psychopathy: Antisocial, Interpersonal, Affective, and Lifestyle. Other available assessments of psychopathy include the Psychopathy Checklist (PCL; Hare, 1980, 2003), which measures two factors, and Psychopathy Personality Inventory (PPI; Lilienfeld & Andrews, 1996), which measures two factors and seven facets (Benning et al., 2003). Although popular measures of psychopathy, including the SRP, PCL, and PPI, generally show good reliability and convergent and discriminant validity (Patrick et al., 2006; Paulhus et al., 2016; Vitale et al., 2002), an established structure of psychopathy is still in question. Recent factor analyses of measures assessing a triarchic model of psychopathy, with aspects of boldness, meanness, and disinhibition (Patrick et al., 2009), suggested there may be five to seven meaningful psychopathy facets (Collison et al., 2020).

Unlike the other DT domains, Machiavellianism does not have etiology in a clinical disorder. Christie and Geis (1970) first used the term to coin a manipulative type of personality, and developed the MACH-IV scale, which provides a composite score of Machiavellianism as well as three facets: Manipulation, Detachment, and Morality. However, the factor structure of the MACH-IV remains unclear, as anywhere from one to five factors have been suggested (Ahmed & Stewart, 1981; Fehr et al., 1992; Rauthmann, 2013). There is a need for a multidimensional measure of Machiavellianism that captures the cognitive, emotional, motivational, and behavioral aspects of this domain (Rauthmann & Will, 2011). Most available measures fail to capture the domain according to expert theoretical descriptions (Miller, Hyatt, et al., 2017). Recently, the Five Factor Machiavellianism Inventory (FFMI; Collison et al., 2018) was developed, which assesses 13 facets of Machiavellianism that can be used to compute a total score as well as three higher order factors: Antagonism, Agency, and Planfulness.

A recent study by Rogoza and Cieciuch (2018) examined the structure of the DT as a whole, and found twelve distinct facets. Using Goldberg's (2006) top-down procedure, a type of factor analysis in which the first level consists of the largest singular factor, the second level the two largest factors, etc., they extracted factor scores from several structural equation modeling analyses with increasing numbers of factors. Interestingly, narcissism separated from the other DT domains at the second level, whereas Machiavellianism and psychopathy were not sufficiently distinct until the eleventh level. These results suggest that the "Dark Dyad" interpretation, which presents a bifactor model of psychopathy-Machiavellianism and narcissism, separately, may be most viable (Egan et al., 2014). Furthermore, it has been suggested that vulnerable narcissism be substituted for grandiose narcissism in the SD3, as factor analyses indicated that the current SD3 assessment of narcissism deviated from the general factor and did not fit with the DT core of callousness and manipulation (Persson et al., 2019). Recent network

analyses of the DT resulted in two dimensions: one containing narcissistic rivalry with psychopathy and Machiavellianism, and a second, separate dimension including agentic narcissism measures (Trahair et al., 2020).

In order to elucidate the nature of the association between DT domains and psychosocial outcomes, it is important to first confirm and establish consensus regarding the facets and structure of these domains. Thus, future research may then be able to link specific facets of the DT with life outcomes, providing a clearer picture of how these domains operate within the personality sphere to influence behavior.

## 1.2. The current study

The current study examined the structure of the DT and explored associations among a comprehensive set of measures that assess DT domains and facets by conducting (1) network analyses of the DT domains, independently and in combination, and (2) an Exploratory Graph Analysis (EGA) of each individual DT domain at the item level, and the collection of DT domains at the facet level.

Building on the idea of using network psychometrics to estimate statistical relationships between variables, EGA was used to identify groups of highly connected nodes as latent variables. Golino and Demetriou (2017) have noted EGA performs particularly well with models in which the latent variables may be highly correlated, which is certainly the case for the DT.

## 2. Methods

### 2.1. Sample and procedure

Sample One consisted of 550 adults, recruited through a university and Amazon MTurk. Participants were removed from the sample if they had: (1) an incomplete response ( $N = 53$ ), (2) invalid completion time ( $\leq 15$  min,  $N = 35$ ), (3) an invalid response pattern (e.g. answering "Agree" and "Strongly Agree" in a repeating pattern,  $N = 101$ ), or (4) extreme acquiescence bias ( $N = 60$ ; see Section I of Supplementary Material for further information). The final Sample One consisted of 301 adults with a mean age of 38.03 years (*range*: 20–78 years). 42.2% of participants were female. Sample Two consisted of 370 adults recruited from Amazon MTurk. Participants were again removed from the sample according to procedures listed above (total  $N = 146$ ). The final Sample Two consisted of 224 adults with a mean age of 40.96 years (*range*: 18–78 years) and 47.3% were female. Participants received detailed information regarding study aims and were asked to sign a consent form electronically. Questionnaires were blinded to control for response bias (e.g. SD3 was labelled "Set A"). University students did not receive compensation for taking part. MTurk workers received \$0.75 upon completion. The study was reviewed and approved by the university's ethics committee.

### 2.2. Measures

DT domains were measured with the Short Dark Triad (SD3; Jones & Paulhus, 2014) and Dirty Dozen (DD; Jonason & Webster, 2010). Additionally, narcissism was assessed using the FFNI – Short Form (FFNI-SF; Sherman et al., 2015) and NPI (Raskin & Hall, 1979). Machiavellianism was assessed using the MACH-IV (Christie & Geis, 1970). Psychopathy was assessed with the SRP-4 (Paulhus et al., 2016). Descriptive statistics, reliability and number of items per scale are included in Table 1 (see Section I of Supplementary Material for further information).

### 2.3. Statistical analyses

#### 2.3.1. Network analysis

Network analysis offers a novel technique for visualizing complex relationships and patterns among many variables as a Gaussian

**Table 1**

Descriptive statistics and reliability for DT scales of both samples.

Variable	Mean (SD)	Variance	Median	Range	Kurtosis	Skew	Items (N)	$\omega$
Sample 1 (N = 301)								
MAC	3.32 (0.77)	0.59	3.44	3.89	-0.35	-0.38	9	0.84
MDD	9.73 (4.08)	16.66	9.00	16.00	-0.68	0.49	4	0.84
TAC	2.65 (0.55)	0.31	2.67	3.78	0.71	0.10	9	0.65
VIE	2.83 (0.54)	0.29	2.89	3.33	0.43	-0.07	9	0.70
NAR	2.82 (0.73)	0.54	2.78	3.89	-0.23	-0.14	9	0.80
NDL	11.45 (4.34)	18.83	12.00	16.00	-0.94	-0.10	4	0.87
NPI	13.66 (9.28)	86.19	12.00	39.00	-0.92	0.30	40	0.93
VNA	48.10 (11.57)	133.94	48.00	57.00	-0.38	-0.32	16	0.87
NRT	36.38 (8.90)	79.15	36.00	46.00	-0.06	0.16	12	0.83
ATG	83.14 (27.15)	737.12	80.00	123.00	-0.72	0.26	32	0.96
EXT	52.55 (13.96)	194.95	53.00	62.00	-0.38	-0.45	16	0.92
PSY	2.26 (0.79)	0.63	2.11	3.67	-0.15	0.59	9	0.90
PDD	8.48 (3.78)	14.26	8.00	16.00	0.27	0.92	4	0.84
INT	40.38 (10.45)	109.24	41.00	60.00	-0.08	0.05	16	0.86
AFF	38.78 (9.89)	97.87	38.00	57.00	-0.34	0.14	16	0.84
LIF	39.62 (10.26)	105.33	39.00	50.00	-0.59	0.19	16	0.84
ANT	29.45 (11.72)	137.33	26.00	51.00	-0.30	0.83	16	0.86
Sample 2 (N = 224)								
MAC	3.29 (0.77)	0.59	3.44	4.00	0.12	-0.59	9	0.85
MDD	10.04 (4.18)	17.47	9.00	15.00	-0.76	0.42	4	0.87
TAC	2.66 (0.53)	0.28	2.67	3.22	0.69	-0.04	9	0.55
VIE	2.82 (0.51)	0.26	2.89	2.78	0.03	-0.30	9	0.66
NAR	2.81 (0.76)	0.58	2.78	3.44	-0.69	-0.16	9	0.83
NDL	11.36 (4.17)	17.38	11.00	16.00	-0.88	0.02	4	0.86
NPI	13.92 (8.76)	76.75	14.50	35.00	-0.89	0.20	40	0.91
VNA	47.55 (11.89)	141.29	49.00	60.00	-0.45	-0.09	16	0.88
NRT	35.63 (8.82)	77.84	36.00	48.00	0.29	0.01	12	0.83
ATG	82.09 (28.12)	791.19	79.00	117.00	-0.92	0.25	32	0.96
EXT	51.50 (13.76)	189.26	53.00	59.00	-0.62	-0.39	16	0.92
PSY	2.23 (0.78)	0.61	2.11	3.11	-0.55	0.51	9	0.90
PDD	8.88 (3.71)	13.79	8.00	14.00	-0.50	0.57	4	0.83
INT	40.30 (10.57)	111.76	40.50	51.00	-0.79	0.03	16	0.87
AFF	38.85 (9.50)	90.32	39.00	42.00	-0.80	-0.05	16	0.83
LIF	38.98 (10.38)	107.65	39.00	51.00	-0.31	0.08	16	0.85
ANT	29.58 (12.06)	145.46	25.00	41.00	-0.98	0.62	16	0.92

Note.  $\omega$  = McDonald's omega. MAC = SD3 Machiavellianism, MDD = DD Machiavellianism, TAC = MACH-IV Manipulation Tactics, VIE = MACH-IV Cynical Views, NAR = SD3 Narcissism, NDL = DD Narcissism, NPI = NPI Narcissism, VNA = FFNI-SF Vulnerable Narcissism, NRT = FFNI-SF Neuroticism, ATG = FFNI-SF Antagonism, EXT = FFNI-SF Extraversion, PSY = SD3 Psychopathy, PDD = DD Psychopathy, INT = SRP-4 Interpersonal Psychopathy, AFF = SRP-4 Affective Psychopathy, LIF = SRP-4 Lifestyle Psychopathy, ANT = SRP-4 Antisocial Psychopathy.

Graphical Model (GGM; Costantini et al., 2015; Epskamp et al., 2018; Epskamp & Fried, 2018). GGMs are undirected, meaning potential associations between variables are not constrained to causal pathways. Therefore, network analysis is particularly suited to the study of personality as it allows for cyclic relationships, accounting for facets or items that may influence each other. For example, the FFNI items "I am comfortable taking on positions of authority" and "Leadership comes easy for me" may link because an individual who is comfortable taking on authority roles thinks that leadership is easy, but also because an individual that finds leadership easy is more comfortable with authority roles. Variables, represented as nodes, within the network are connected via edges, which represent partial correlations, indicating that two variables are only connected if there is still a correlation after controlling for all other variables within the network (Costantini et al., 2015). Edges may be regularized through penalty techniques such as the LASSO (Friedman et al., 2008), which shrinks small correlations to zero.

Networks were estimated on multivariate normal data using the *qgraph* (Epskamp et al., 2012) and *bootnet* (Epskamp et al., 2018) packages as part of the R Statistical Software package (R Core Team, 2017). Separate facet level networks were estimated for narcissism, psychopathy, and Machiavellianism, and the DT cluster as a whole. The NPI was removed from the total DT network as it was an additional measure of narcissism and would skew centrality indices by exerting more influence on other nodes. For all networks, an extended Bayesian Information Criterion (EBIC) hyperparameter (gamma) of 0.50 was utilized, as this is the recommended value to achieve specificity while also allowing for sensitivity (Epskamp & Fried, 2018). Stability of

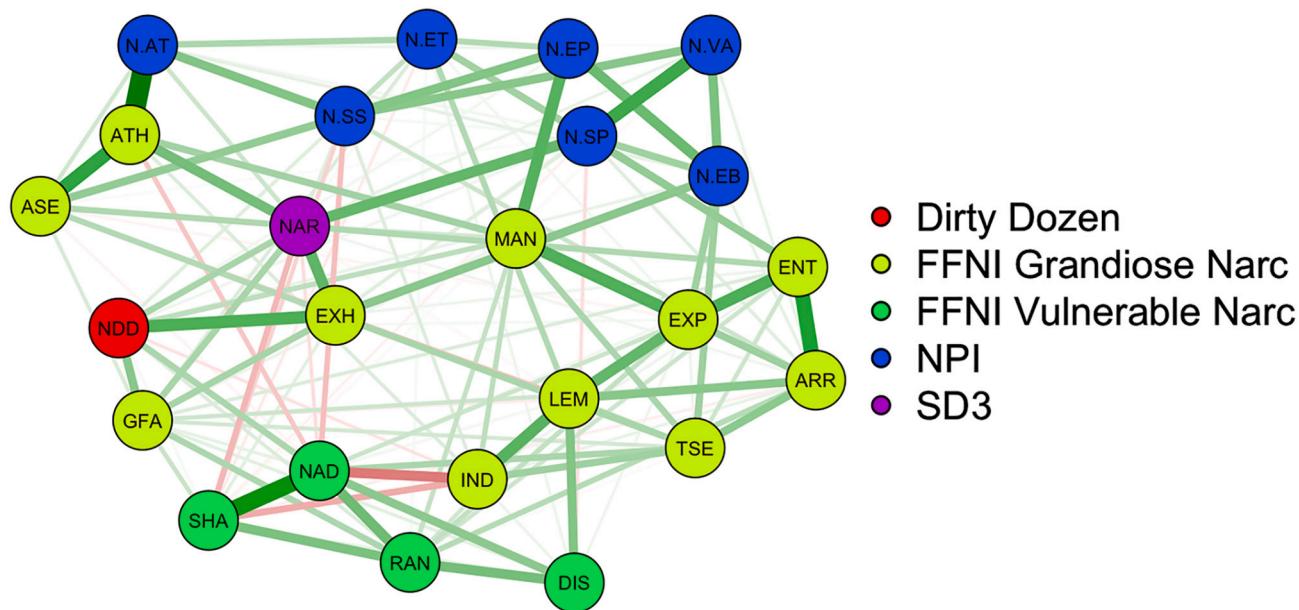
networks was tested with case-dropping and non-parametric bootstraps using 1000 samples (Epskamp et al., 2018). Centrality indices and clustering were examined in order to assess importance of DT traits within each network (see Section II of Supplementary Material for further information).

### 2.3.2. Exploratory Graph Analysis

EGA was utilized to evaluate dimensional structures of narcissism, psychopathy, and Machiavellianism, separately, and as a DT cluster. Each domain was evaluated starting at the item level, and the DT at the facet level.

Recent work has shown that psychometric network models may be used to derive a number of latent dimensions in psychological and personality data (Golino & Epskamp, 2017). Nodes within a network may form *clusters*, which occurs when many of the nodes within a section are connected to each other, or *cliques*, which occurs when all nodes are fully connected within a section. These clusters or cliques may be understood as latent dimensions within a network. For example, EGA has identified facets within personality networks of openness to experience (Christensen, Cotter, Silvia, 2019) as well as symptom dimensions of psychopathology networks (Christensen, Gross, et al., 2019).

Networks were analyzed using the *EGAnet* package (Golino & Christensen, 2020) in R. First, items were removed from the dataset if they had high correlations ( $r > 0.65$ ), identical wording, or cross-loaded onto multiple facets (see Section II of Supplementary Material for further information). Next, models were estimated using a Triangulated Maximally Filtered Graph (TMFG) and the walktrap community detection

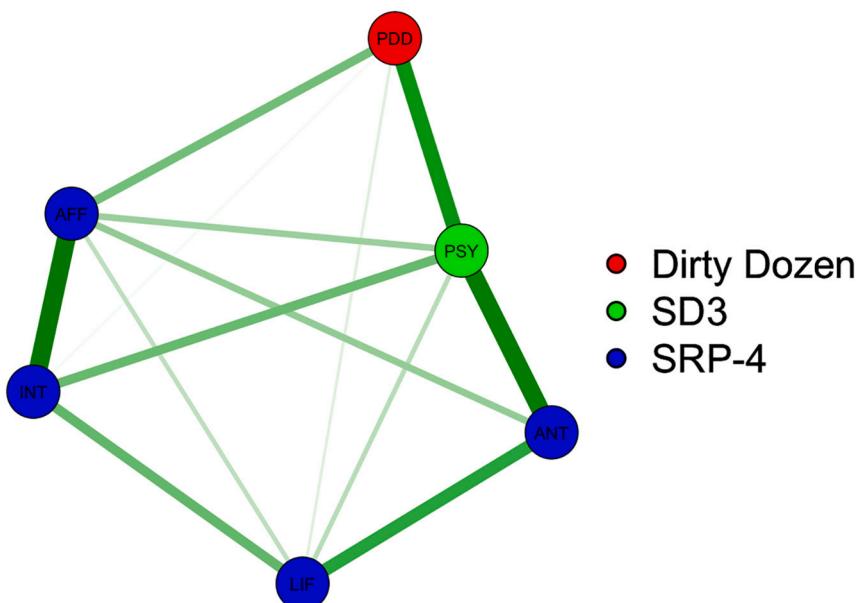


**Fig. 1.** Network of narcissism. Nodes represent FFNI-SF, NPI, SD3 and DD scales. Thickness of lines between nodes represents edge weights. Green lines are positive connections, and red lines are negative. FFNI-SF: ASE = Acclaim Seeking, ARR = Arrogance, ATH = Authoritativeness, DIS = Distrust, ENT = Entitlement, EXH = Exhibitionism, EXP = Exploitativeness, GFA = Grandiose Fantasies, IND = Indifference, LEM = Lack of Empathy, MAN = Manipulativeness, NAD = Need for Admiration, RAN = Reactive Anger, SHA = Shame, TSE = Thrill Seeking; NPI: N.AT = Authority, N.EB = Exhibitionism, N.EP = Exploitativeness, N.NET = Entitlement, N.SP = Superiority, N.SS = Self-sufficiency, N.VA = Vanity; NAR = Narcissism SD3; NDD = Narcissism DD. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

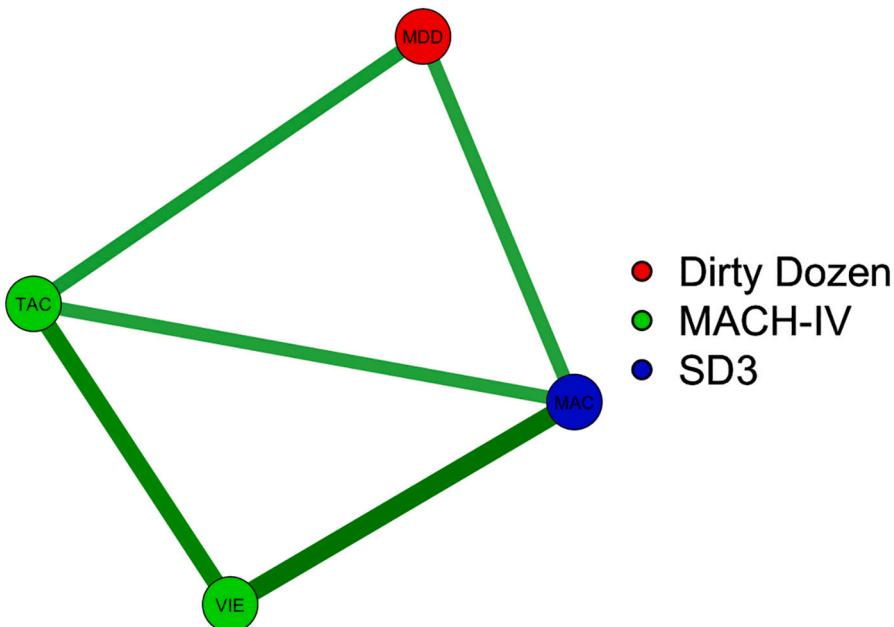
algorithm, which trims a network to contain 3- and 4-node cliques based on zero-order correlations and retains a total of  $3n - 6$  edges from the original network ( $n$  = number of nodes; Golino et al., 2020). At the item level, cliques may be interpreted as facets, which upon further analyses may group together as higher order factors (Christensen et al., 2019).

The stability of initial item level EGA networks was tested with the bootstrap exploratory graph analysis (*bootEGA*) approach and *dimStability* function. The *bootEGA* function can be used to compute item stability and structural consistency of EGA networks by simulating

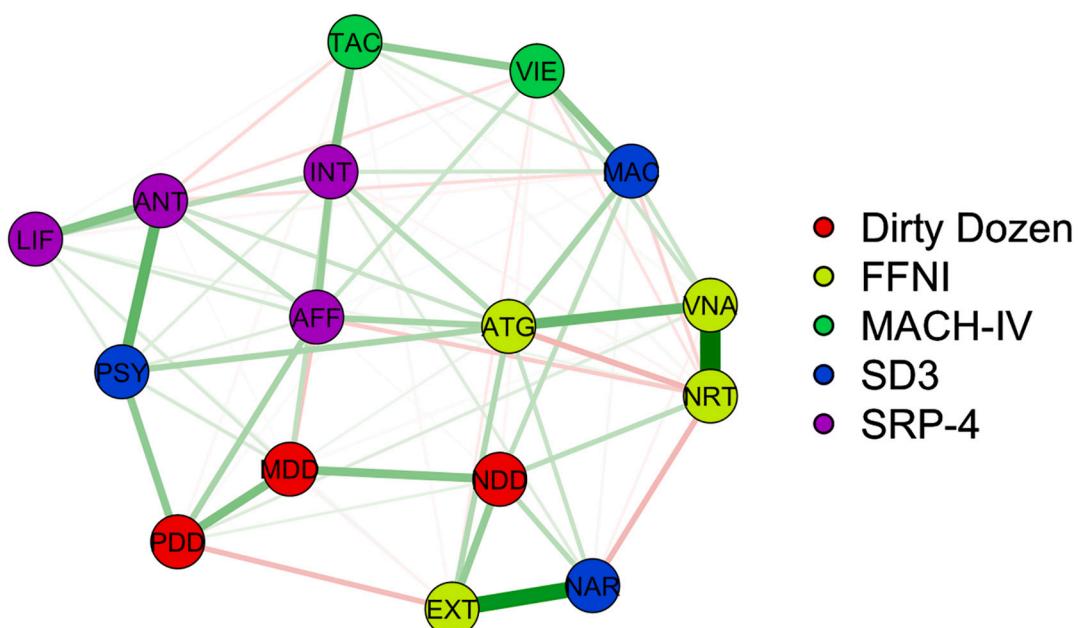
multivariate normal networks based on original data (Christensen & Golino, 2019; see Section IV of the Supplementary Material for further information). A second round of EGAs were run to explore higher order factors for each facet-level model. The second EGA models were estimated using a graphical LASSO algorithm with EBIC model selection, as this regularization technique is stricter with spurious connections (Epskamp & Fried, 2018). Crucially, initial structural networks of the DT domains were then cross-validated in the second, separate sample (Picard & Cook, 1984).



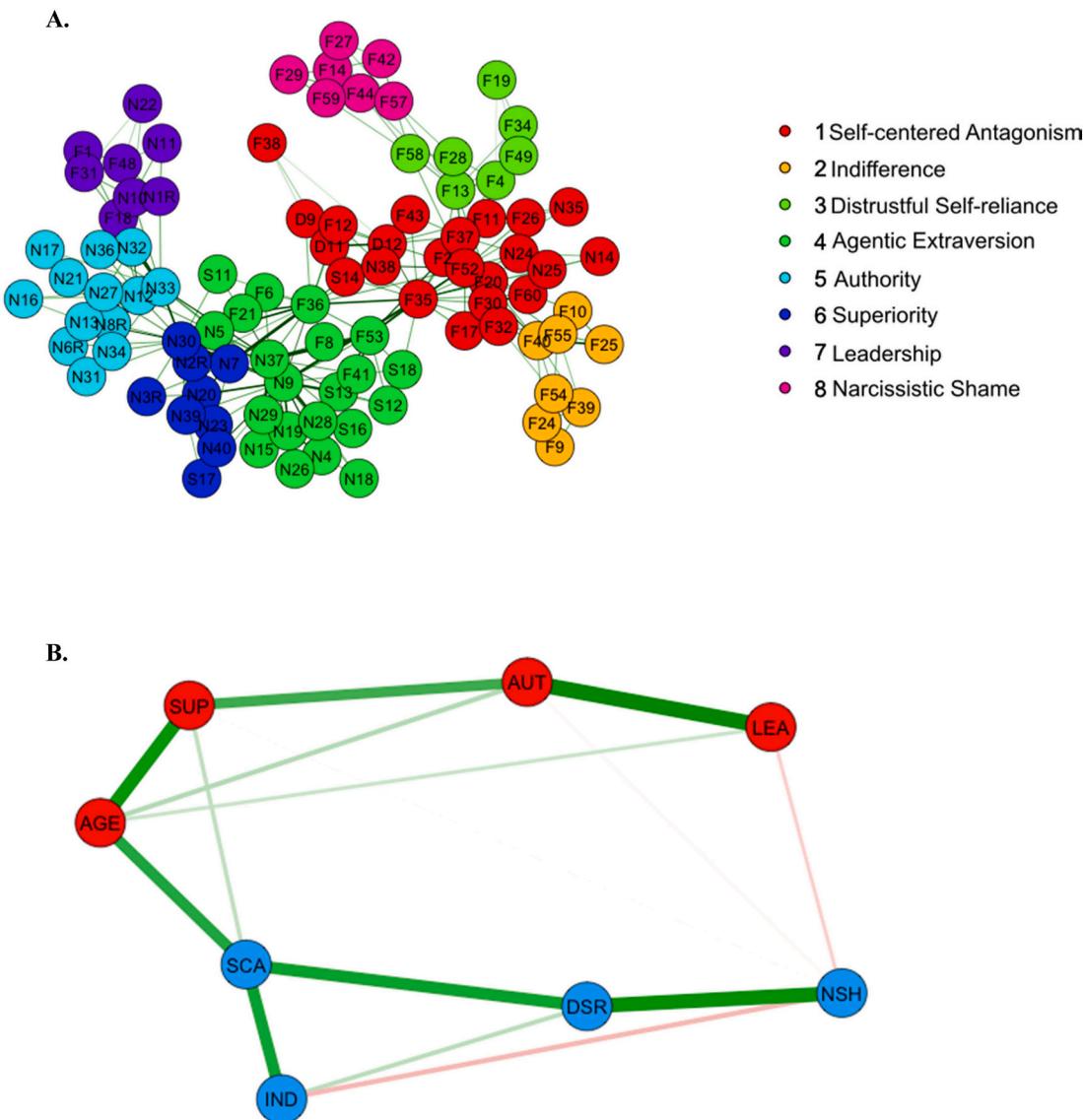
**Fig. 2.** Network of psychopathy. Nodes represent SRP-4, SD3, and DD scales. Thickness of lines between nodes represents edge weights. Green lines are positive connections, and red lines are negative. AFF = Affective, ANT = Antisocial, INT = Interpersonal, LIF = Lifestyle, PDD = Psychopathy (DD), PSY = Psychopathy (SD3). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)



**Fig. 3.** Network of Machiavellianism. Nodes represent MACH-IV, SD3, and DD scales. Thickness of lines between nodes represents edge weights. Green lines are positive connections, and red lines are negative. MAC = Machiavellianism (SD3), MDD = Machiavellianism (DD), TAC = Tactics, VIE = Views. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)



**Fig. 4.** Network of the DT. Nodes represent FFNI, MACH-IV, SRP-4, SD3, and DD scales. Thickness of lines between nodes represents edge weights. Green lines are positive connections, and red lines are negative. AFF = Affective, ATG = Antagonism, ANT = Antisocial, EXT = Extraversion, INT = Interpersonal, LIF = Lifestyle, MAC = Machiavellianism SD3, MDD = Machiavellianism DD, NAR = Narcissism SD3, NDD = Narcissism DD, NRT = Neuroticism, PDD = Psychopathy DD, PSY = Psychopathy SD3, TAC = Manipulation Tactics, VIE = Cynical Views, VNA = Vulnerable Narcissism. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)



**Fig. 5.** A. EGA of FFNI-SF, NPI, SD3 and DD narcissism items with Sample 1. B. EGA of the eight facet narcissism model with Sample 1. Two factors were suggested. C. EGA of FFNI-SF, NPI, SD3 and DD narcissism items with Sample 2. Eight facets were suggested in both samples. D. EGA of the eight facet narcissism model with Sample 2. Four factors were suggested. AGE = Agentic Extraversion, ASK = Acclaim-seeking, AUT = Authority, DSR = Distrustful Self-reliance, IND = Indifference, LEA = Leadership, NSH = Narcissistic Shame, SCA = Self-centered Antagonism, SUP = Superiority.

### 3. Results

#### 3.1. Descriptive statistics

#### 3.2. Networks of the Dark Triad

##### 3.2.1. Narcissism network

The network of narcissism, including FFNI-SF, SD3, DD, and NPI scales, is presented in Fig. 1. Nodes representing Narcissism (SD3) and NPI scales were positively connected to aspects of grandiose narcissism, as measured by the FFNI-SF. However, Narcissism (DD) was linked to both grandiose and vulnerable narcissism. The strongest link between facets of grandiose and vulnerable narcissism was a negative association between Need for Admiration and Indifference. See Section III of Supplementary Material for centrality and clustering of all DT networks.

##### 3.2.2. Psychopathy network

The network of psychopathy, including SRP-4, SD3, and DD scales, is presented in Fig. 2. Psychopathy (SD3) was directly linked to all facets measured by the SRP-4 and Psychopathy (DD). The links between Psychopathy (SD3) and Antisocial and Interpersonal facets were the strongest. Psychopathy (DD) showed the strongest links to Psychopathy (SD3) and Affective psychopathy (SRP-4).

##### 3.2.3. Machiavellianism network

The network of Machiavellianism, including SD3, DD, and MACH-IV scales, is presented in Fig. 3. Machiavellianism (SD3) was linked to all nodes. Machiavellianism (DD) was directly linked to Manipulation Tactics and Machiavellianism (SD3).

##### 3.2.4. Dark Triad network

The total DT network, including FFNI-SF, SRP-4, MACH-IV, DD, and SD3 scales, is presented in Fig. 4. All DT traits measured by the DD were positively connected, although the association between narcissism and

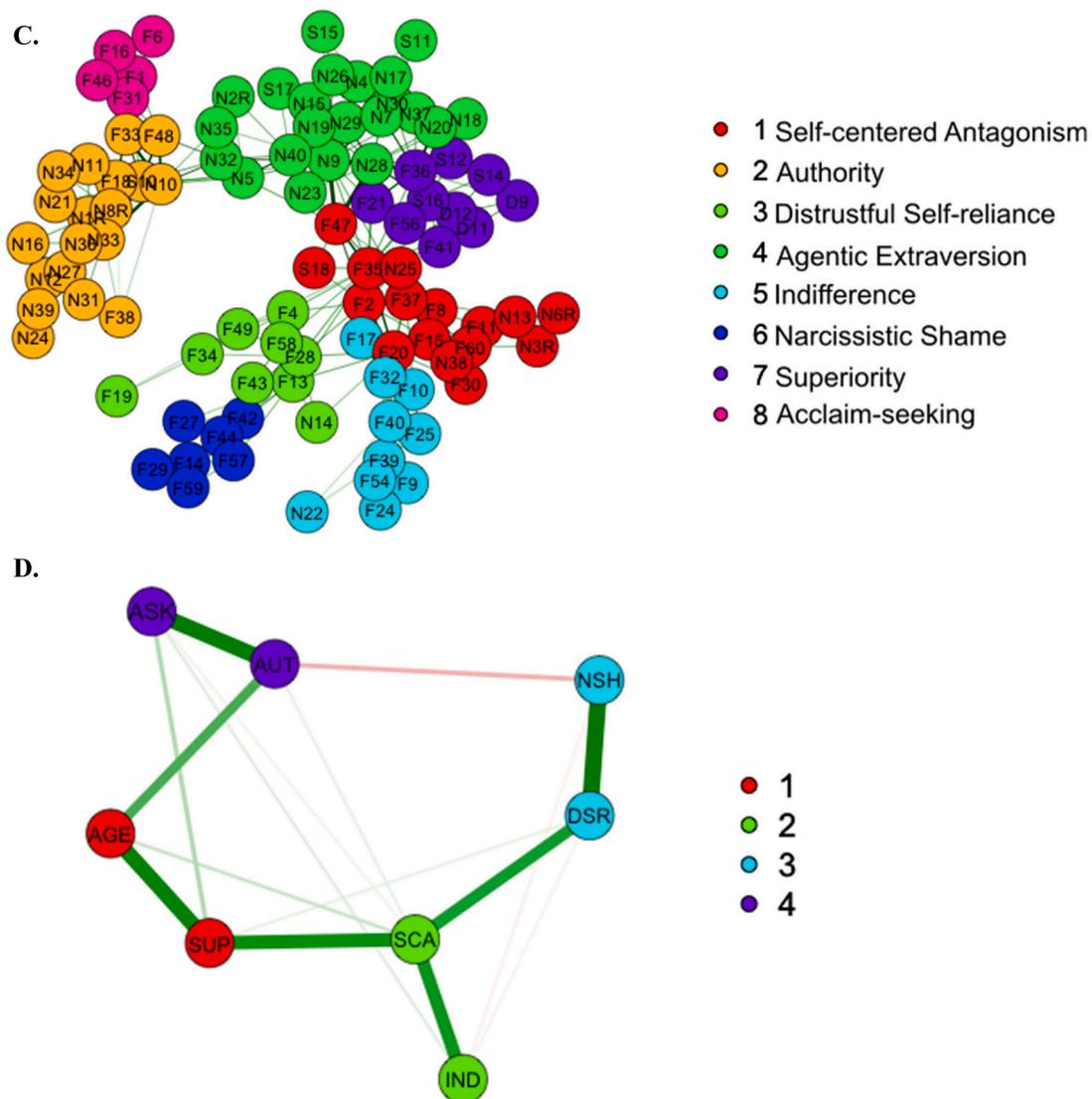


Fig. 5. (continued).

psychopathy was weak. On the other hand, DT traits measured by the SD3 were not directly connected. Instead, they grouped together with their respective domain facets (e.g. SD3 Psychopathy with SRP-4 scales). Narcissism (SD3) showed a strong, positive connection to Extraversion. Vulnerable Narcissism was positively associated with Antagonism and Neuroticism, and weakly with Machiavellianism (SD3 and MACH-IV). Psychopathy (SD3), Affective psychopathy, and Interpersonal psychopathy were moderately associated with Antagonism. Psychopathy (SD3), Lifestyle psychopathy, and Antisocial psychopathy were strongly, positively connected. Machiavellianism (SD3) was connected to Antagonism and Vulnerable Narcissism.

### 3.3. Exploratory Graph Analysis of the Dark Triad

#### 3.3.1. Narcissism EGA: sample 1

The EGA of FFNI-SF, NPI, SD3, and DD narcissism items is presented in Fig. 5A. Of the 96 included items, eight facets were identified. Facet labels, example items, and reliability estimates are presented in Table 2. Facet 1 (*Self-centered Antagonism*) contained 14 FFNI-SF items, five NPI items, three DD items, and one SD3 item. These items represent entitlement, reactive anger, and distrust. Facet 2 (*Indifference*) included eight FFNI-SF items, four from the Indifference scale, and four from the Lack of Empathy scale. Facet 3 (*Distrustful Self-reliance*) included seven

FFNI-SF items, which originally loaded onto Reactive Anger and Distrust scales of the FFNI-SF. Facet 4 (*Agentic Extraversion*) captured six FFNI-SF items, ten NPI items, and five SD3 items characteristic of manipulation, exhibitionism, and acclaim-seeking. Facet 5 (*Authority*) included 13 NPI items, most of which loaded onto NPI Self-sufficiency and Authority scales. Facet 6 (*Superiority*) included eight NPI items and one SD3 item characteristic of both entitlement and exhibitionism. Facet 7 (*Leadership*) contained four FFNI-SF items and four NPI items describing a person that takes on leadership roles and works to achieve long-term goals. Facet 8 (*Narcissistic Shame*) included seven FFNI-SF items highlighting a need for approval and tendency to feel shame.

The second EGA of the eight facets suggested a two-factor model (see Fig. 5B), indicative of (1) Grandiose Narcissism, including: Agentic Extraversion, Superiority, Authority, and Leadership; and (2) Vulnerable Narcissism, including: Self-centered Antagonism, Indifference, Distrustful Self-reliance, and Narcissistic Shame. See Section IV of the Supplementary Material for information on CFAs of all DT EGA models.

#### 3.3.2. Narcissism EGA: sample 2

The EGA of FFNI-SF, NPI, SD3, and DD narcissism items is presented in Fig. 5C. Of the 98 included items, eight facets were identified. Facet labels, example items, and reliability estimates are presented in Table 2. The eight facet structure identified in Sample 1 replicated in Sample 2

with some variation in the item content of facets. However, Leadership did not emerge as one of the facets. A new facet that was interpreted as Acclaim-seeking was identified.

The validation model differed from the original model in that four higher order factors were suggested (see Fig. 5D), representative of (1) Narcissistic Extraversion, including: Agentic Extraversion and Superiority; (2) Antagonism, including: Self-centered Antagonism and Indifference; (3) Narcissistic Neuroticism, including: Narcissistic Shame and Distrustful Self-reliance; and (4) Ambition, including: Authority and Acclaim-seeking.

### 3.3.3. Psychopathy EGA: sample 1

The EGA of SRP-4, SD3, and DD psychopathy items is presented in Fig. 6A. Of the 74 included items, six facets were identified. Facet labels, example items, and reliability estimates are presented in Table 3. Facet 1 (*Thrill-Seeking*) included 16 SRP-4 items and two SD3 items characteristic of risk-taking and antagonistic behavior. Facet 2 (*Manipulation*) contained nine SRP-4 items describing a propensity for manipulating others and a disregard for commitments. Facet 3 (*Aggression/Impulsivity*) included ten SRP-4 items and six SD3 items characteristic of vengeful and impulsive behavior. Facet 4 (*Antisocial*) contained 16 SRP-4 items describing unlawful behavior and serious criminal offenses. Facet 5 (*Detachment*) included five SRP-4 items and three DD items relating to cold and distant affect. Facet 6 (*Interpersonal*) included seven SRP-4 items, most of which belonged to the SRP-4 Interpersonal psychopathy scale. These items describe callous interactions with others.

The second EGA of the six facets suggested a two-factor model (see Fig. 6B), representative of (1) Antisociality, including: Antisocial psychopathy, Aggression/Impulsivity, Detachment, and Manipulation; and (2) Relational Aggression, including: Interpersonal psychopathy and Thrill-Seeking.

**Table 2**  
Facets derived from the EGA of narcissism.

	Facet label	Example item	Reliability
<b>Sample 1 (N = 301)</b>			
Facet 1	Self-centered Antagonism	"It may seem unfair, but I deserve extra"	$\omega = 0.92$
Facet 2	Indifference	"I don't worry about others' needs"	$\omega = 0.85$
Facet 3	Distrustful Self-reliance	"I'm slow to trust people"	$\omega = 0.78$
Facet 4	Agentic Extraversion	"I want to amount to something in the eyes of the world"	$\omega = 0.92$
Facet 5	Authority	"I always know what I am doing"	$\omega = 0.85$
Facet 6	Superiority	"I am an average person" (reversed)	$\omega = 0.79$
Facet 7	Leadership	"I aspire for greatness"	$\omega = 0.84$
Facet 8	Narcissistic Shame	"I feel ashamed when people judge me"	$\omega = 0.83$
<b>Sample 2 (N = 224)</b>			
Facet 1	Self-centered Antagonism	"It may seem unfair, but I deserve extra"	$\omega = 0.91$
Facet 2	Authority	"I always know what I am doing"	$\omega = 0.89$
Facet 3	Distrustful Self-reliance	"I'm slow to trust people"	$\omega = 0.81$
Facet 4	Agentic Extraversion	"I want to amount to something in the eyes of the world"	$\omega = 0.89$
Facet 5	Indifference	"I don't worry about others' needs"	$\omega = 0.85$
Facet 6	Narcissistic Shame	"I feel ashamed when people judge me"	$\omega = 0.82$
Facet 7	Superiority	"I tend to seek prestige or status"	$\omega = 0.90$
Facet 8	Acclaim-seeking	"I am driven to succeed"	$\omega = 0.84$

### 3.3.4. Psychopathy EGA: sample 2

The EGA of SRP-4, SD3, and DD psychopathy items is presented in Fig. 6C. Of the 69 included items, six facets were identified. Facet labels, example items, and reliability estimates are presented in Table 3. The six facet structure identified in Sample 1 replicated in Sample 2, with some variation in item content of the facets. Antisocial, Aggression/Impulsivity, Manipulation, Detachment, and Thrill-Seeking replicated in Sample 2. A new factor labelled Risky Behavior emerged in Sample 2, instead of Interpersonal psychopathy.

A second EGA was run to explore higher order factors (see Fig. 6D). The validation model differed from the original in that one higher order factor was suggested.

### 3.3.5. Machiavellianism EGA: sample 1

The EGA of MACH-IV, SD3, and DD Machiavellianism items is presented in Fig. 7A. Of the 30 included items, four facets were identified. Facet labels, example items, and reliability estimates are presented in Table 4. Facet 1 (*Manipulation*) contained four DD items and two MACH-IV items characteristic of interpersonal manipulation. Facet 2 (*Morality*) contained eight MACH-IV items describing a general lack of morality and ethical standards. Facet 3 (*Detachment*) included five SD3 items and one MACH-IV item highlighting a lack of empathy and dissociation from others. Facet 4 (*Cynicism*) included seven MACH-IV items and three SD3 items characteristic of cynical views of others and the overall social world.

The second EGA of the four facets suggested a one-factor model (see Fig. 7B).

### 3.3.6. Machiavellianism EGA: sample 2

The EGA of MACH-IV, SD3, and DD Machiavellianism items is presented in Fig. 7C. Of the 30 included items, four facets were identified. Facet labels, example items, and reliability estimates are presented in Table 4. The four facets identified in Sample 1 replicated with Sample 2 with some variation in the item content of facets. In Sample 2, Morality was connected to the other facets through Cynicism, rather than Manipulation as was found in the Sample 1 model.

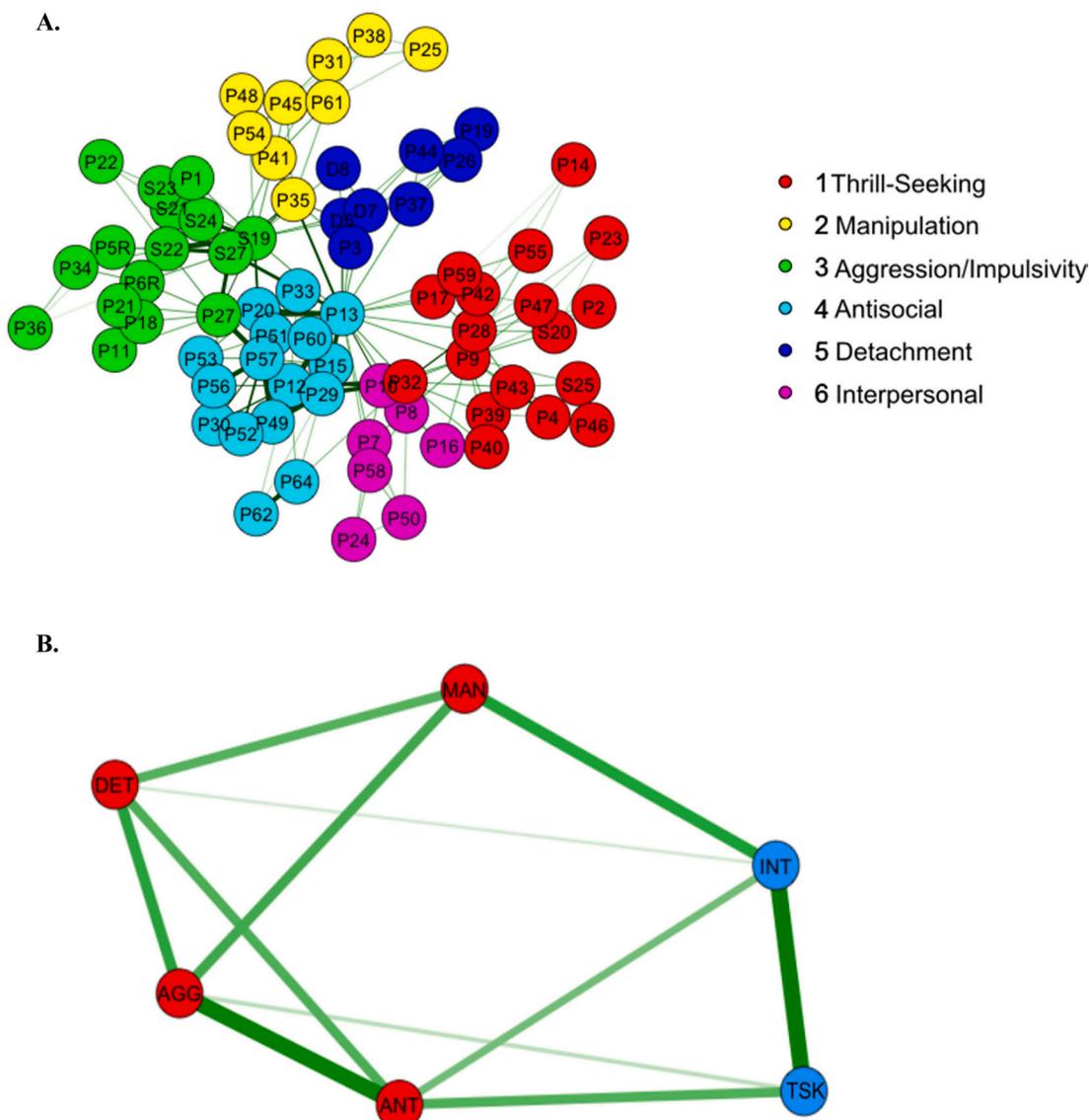
Similar to Sample 1, the second EGA suggested a one-factor model of the four facets (see Fig. 7D).

### 3.3.7. Dark Triad EGA: sample 1

The EGA of the DT, including the eight narcissism facets, six psychopathy facets, and four Machiavellianism facets suggested by prior EGAs, is presented in Fig. 8A. Of the total 18 facets, four higher order factors were identified. Factor 1 comprised all Machiavellianism facets, including Morality, Manipulation, Detachment, and Cynicism. Factor 2 comprised Agentic Extraversion, Superiority, Authority, and Leadership; all facets stemming from grandiose narcissism. Factor 3 included Self-centered Antagonism, Indifference, Distrustful Self-reliance, and Narcissistic Shame; all facets stemming from the antagonistic and vulnerable side of narcissism. Factor 4 comprised all psychopathy facets, including Detachment, Aggression/Impulsivity, Manipulation, Antisocial psychopathy, Interpersonal psychopathy, and Thrill-Seeking.

### 3.3.8. Dark Triad EGA: sample 2

The EGA of the DT, including the 18 facets previously identified, is presented in Fig. 8B. The four factors identified with Sample 1 did not replicate with Sample 2. Of the total 18 facets, six higher order factors were identified. Factor 1 comprised Detachment, Cynicism, and two Manipulation facets, stemming from both psychopathy and Machiavellianism. Three narcissism factors emerged (Factors 2, 4, and 6), indicative of Grandiose Narcissism, Narcissistic Neuroticism, and Antagonism, respectively. Factor 3 included psychopathy facets of Aggression/Impulsivity, Antisocial psychopathy, Thrill-Seeking, and Risky Behavior. Factor 5 comprised Detachment (psychopathy) and Morality (Machiavellianism).



**Fig. 6.** A. EGA of SRP-4, SD3 and DD psychopathy items with Sample 1. B. EGA of the six facet original model with Sample 1. Two higher order factors were suggested. C. EGA of SRP-4, SD3 and DD psychopathy items with Sample 2. Six facets were suggested with both samples. D. EGA of the six facet original model with Sample 2. One higher order factor was suggested. AGG = Aggression/Impulsivity, ANT = Antisocial, DET = Detachment, INT = Interpersonal, MAN = Manipulation, RSB = Risky Behavior, TSK = Thrill-Seeking.

#### 4. Discussion

The current study provides further evidence towards the multidimensionality of the DT, utilizing novel dimension reduction techniques and a cross-validation sample. EGA analyses suggested eight facets of narcissism, six facets of psychopathy, four facets of Machiavellianism, and four DT factors. Networks of DT domains indicated the majority of available measures assessing the DT may not be comprehensive enough to capture all facets, and that there is a need for broader trait conceptualizations.

##### 4.1. Dark Triad facet associations

In the narcissism network, both NPI and SD3 scales were solely connected to facets of grandiose narcissism. As the NPI was created as a measure of grandiose, overt narcissism (Pincus & Lukowitsky, 2010), results affirm this scale captures its intended domain. SD3 narcissism was most strongly associated with Superiority, Authority, and Exhibitionism.

The DD scale, however, was linked to both grandiose and vulnerable facets. Maples et al. (2014) also found the DD scale was moderately correlated with both vulnerable and grandiose narcissism, whereas the SD3 scale was solely strongly associated with grandiose narcissism. Our results augment prior research by identifying which narcissistic facets are captured by the SD3 and DD.

Furthermore, the strong, negative association between Indifference and Need for Admiration indicates the dichotomy between vulnerable and grandiose narcissism stems from the separate embodiment of these facets. Vulnerable and grandiose narcissism were positively linked through Reactive Anger, Distrust and Lack of Empathy. Prior research on the structure of narcissism (Krizan & Herlache, 2018; Miller et al., 2011; Miller et al., 2017) also found the primary connection between vulnerable and grandiose narcissism profiles was an antagonistic interpersonal orientation.

In the psychopathy network, the SD3 psychopathy scale primarily captured Antisocial and Interpersonal psychopathy, and the DD psychopathy scale primarily captured Affective and Antisocial psychopathy.

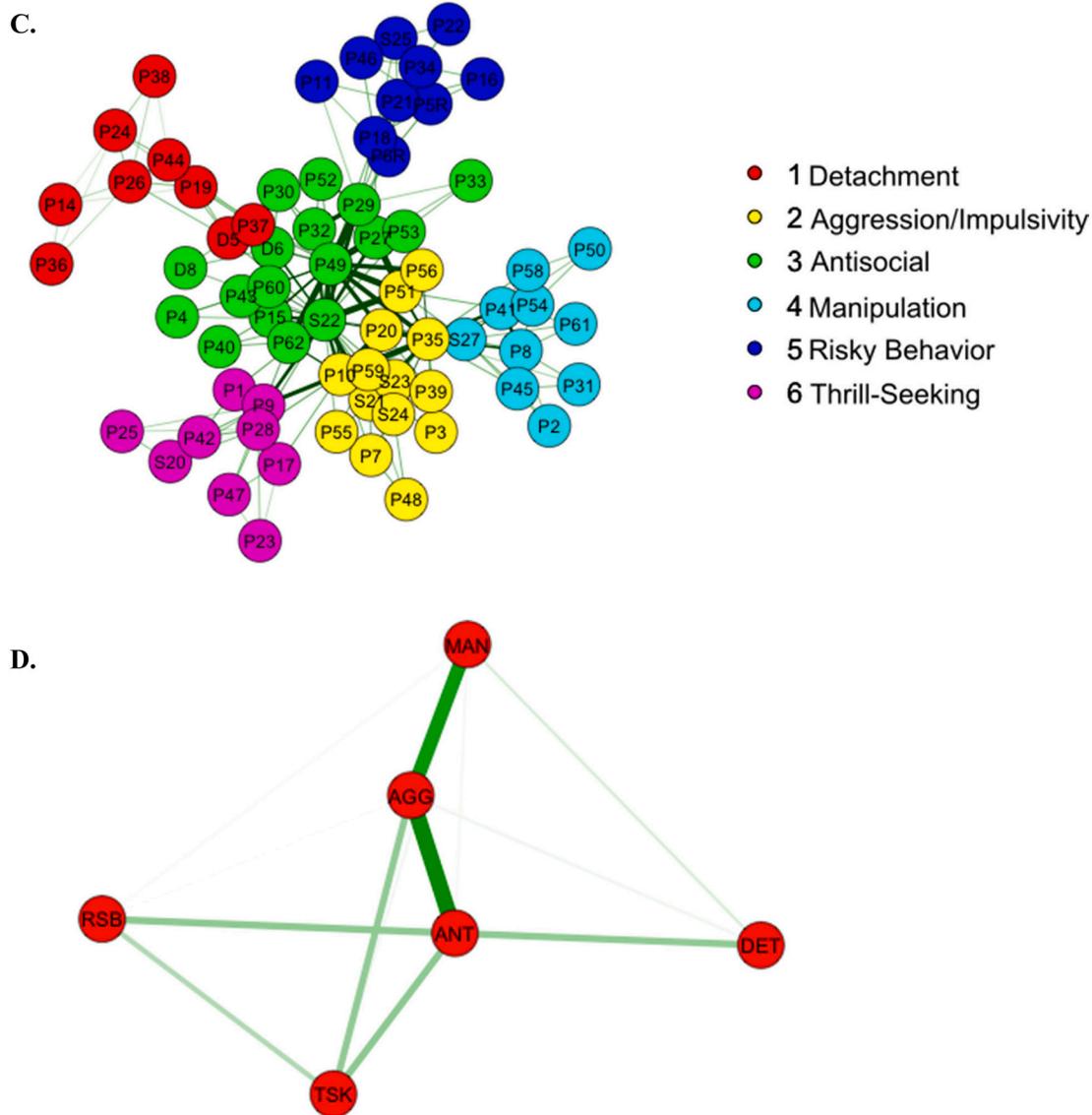


Fig. 6. (continued).

Prior research found the DD psychopathy scale was most strongly associated with Callous Affect, as measured by the SRP-3 (Paulhus et al., 2009), and the SD3 psychopathy scale was strongly associated with all SRP-3 factors (Maples et al., 2014).

In the Machiavellianism network, the SD3 scale was directly associated with all included facets. Items on the SD3 aligned with both cynical worldview and manipulativeness (Jones & Paulhus, 2014). However, the DD scale primarily captured manipulativeness, and was indirectly associated with cynical worldview. All items on the DD scale appear to be indicative of manipulativeness. Both SD3 and DD scales have shown strong associations with the MACH-IV total Machiavellianism score previously (Maples et al., 2014). Our results indicate that the DD provides an assessment of specific facets of psychopathy and Machiavellianism, rather than the comprehensive domains.

In the DT network, Antagonism, assessed by the FFNI-SF, was the most central trait within the DT cluster. Facets from both vulnerable and grandiose narcissism are used to score Antagonism, including Manipulativeness, Exploitativeness, Entitlement, Lack of Empathy, Arrogance, Reactive Anger, Distrust, and Thrill-Seeking. Furthermore, the connection between Machiavellianism and psychopathy appeared to operate indirectly through Antagonism. Results suggest that the aforementioned facets of Antagonism link the DT domains together.

#### 4.2. Structure of Dark Triad domains

Structural analyses of narcissism indicated that facets were primarily linked through network-identified Self-centered Antagonism and Agentic Extraversion in both initial and validation models. Antagonism has previously been identified as an important facet linking vulnerable and grandiose narcissism together (Krizan & Herlache, 2018; Miller et al., 2016). In Crowe et al. (2019) recent structural analysis of narcissism, Self-centered Antagonism emerged with Narcissistic Neuroticism and Agentic Extraversion when three factors were extracted from the item pool. The narcissism model identified in the validation sample suggested four higher order factors, in which antagonism served as a bridge between vulnerable and grandiose narcissism.

Furthermore, from the network structure it can be inferred that Superiority is strongly associated with Agentic Extraversion, whereas Authority and Leadership are more peripheral. In the validation sample, Authority and Acclaim-seeking formed an entirely separate factor, which we labelled Ambition. It is possible that items assessing these facets may capture a separate domain of narcissism relevant to proactive behavior and achievement. Previous associations found between narcissism and prosocial traits and outcomes such as Mental Toughness (Onley et al., 2013), lower perceived stress (Papageorgiou, Giannou,

**Table 3**  
Facets derived from the EGA of psychopathy.

Facet label	Example item	Reliability
Sample 1 ( <i>N</i> = 301)		
Facet 1	Thrill-Seeking “I don’t enjoy taking risks (reversed)”	$\omega = 0.85$
Facet 2	Manipulation “I can talk people into anything”	$\omega = 0.77$
Facet 3	Aggression/ Impulsivity “People often say I’m out of control”	$\omega = 0.89$
Facet 4	Antisocial “I was convicted of a serious crime”	$\omega = 0.91$
Facet 5	Detachment “People sometimes say that I’m cold-hearted”	$\omega = 0.82$
Facet 6	Interpersonal “Most people tell lies every day”	$\omega = 0.75$
Sample 2 ( <i>N</i> = 224)		
Facet 1	Detachment “People sometimes say that I’m cold-hearted”	$\omega = 0.68$
Facet 2	Aggression/ Impulsivity “I admit that I often mouth off without thinking”	$\omega = 0.91$
Facet 3	Antisocial “I was convicted of a serious crime”	$\omega = 0.92$
Facet 4	Manipulation “I’ll say anything to get what I want”	$\omega = 0.83$
Facet 5	Risky Behavior “I have never been involved in delinquent gang activity” (reversed)	$\omega = 0.80$
Facet 6	Thrill-Seeking “I enjoy doing wild things”	$\omega = 0.80$

et al., 2019) and fewer symptoms of depression (Papageorgiou, Denovan, & Dagnall, 2019), may in part be explained by the use of the SD3 or NPI, which captured facets of Superiority, Authority, and Exhibitionism. In regards to vulnerable narcissism facets, Narcissistic Shame and Indifference were peripherally located. Narcissistic Shame was strongly negatively linked to Leadership and Indifference in the original sample and to Authority in the validation sample, suggesting these facets of narcissism are most opposed to one another. These antagonistic facets may therefore serve as the links between narcissism and other DT domains.

In structural analyses of psychopathy, initial and validation models suggested six facets, including Thrill-Seeking, Antisocial psychopathy, Aggression/Impulsivity, Manipulation, Detachment, Interpersonal psychopathy (initial sample), and Risky Behavior (validation sample). Collison et al. (2020) found that six factor models had the best fit with several different measures of psychopathy, and identified traits similar to those in the current study, such as Coldness, Impulsivity, Antisociality, Relational Aggression, and Sensation-Seeking. In both initial and validation networks, Antisocial psychopathy was most central and served as a connector between other facets within the network. Prior network analyses have highlighted the centrality of callousness/lack of empathy and lack of guilt, core characteristics of antisocial psychopathy, to the psychopathy domain (Verschueren et al., 2018). Smaller facets of detachment and manipulation were peripherally located in the psychopathy network, suggesting these are facets that may overlap with other domains (Christensen et al., 2019), such as narcissism and Machiavellianism.

In structural analyses of Machiavellianism, initial and validation models suggested four facets, including Manipulation, Cynicism, Detachment and Morality. This four facet model is more comprehensive than most routinely used measures of Machiavellianism, including the MACH-IV, SD3, and DD. In factor analyses of DT domains, Machiavellianism and psychopathy appear redundant (Egan et al., 2014; Rogoza & Cieciuch, 2017; Vize et al., 2018), evidencing nearly 80% shared variance (Miller, Hyatt, et al., 2017). In the DT EGA of the validation sample, one factor included both psychopathy and Machiavellianism facets, providing further support for the conceptual overlap between these two domains. Results suggest this overlap primarily operates through the strong association between facets of manipulation, immorality, and

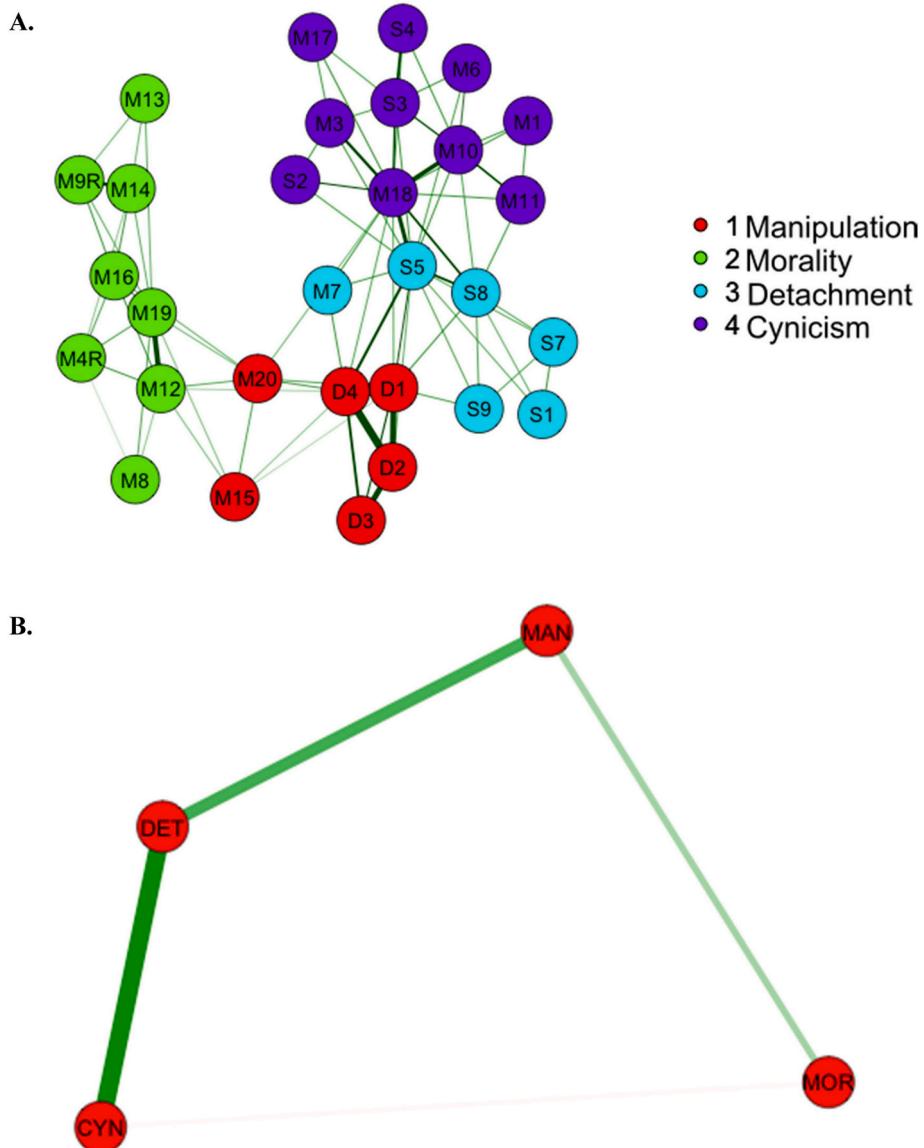
detachment. It is reasonable to suggest that redundancy between Machiavellianism and psychopathy is not due to such extreme similarity between the two, but because Machiavellianism has yet to be properly assessed. Recent work by Collison et al. (2018) to develop the FFMI may hopefully provide a clearer picture of Machiavellianism within the personality sphere.

In structural analyses of the DT, vulnerable and grandiose narcissism facets formed separate factors in both initial and validation samples. This factor structure has important implications for assessments of the DT that include only grandiose narcissism, such as the SD3 or NPI. Persson et al. (2019) argued that vulnerable narcissism should replace grandiose narcissism in the SD3, as this is a more likely source of narcissistic hostility and aggression. Our results are not consistent with this suggestion; indeed, it is a combination of grandiose and vulnerable narcissistic facets that should be incorporated. Self-centered Antagonism occupied a central position in both initial and validation networks, linking grandiose and vulnerable narcissism facets to psychopathy and Machiavellianism. In Dinić et al.’s (2020) network analysis of the Dark Tetrad (an expanded DT model including sadism), narcissism was found to be redundant, yet in the current study it appears to be crucial to the DT structure. Antagonism not only bridges the gap between vulnerable and grandiose narcissism (Crowe et al., 2019; Krizan & Herlache, 2018; Miller et al., 2011, 2016; Miller, Hyatt, et al., 2017), but also brings together the DT domains into a more theoretically and empirically sound cluster.

#### 4.3. Implications for personality assessment

Overall, these findings have implications for personality structure and assessment, especially in regards to the DT. Research has shown that DT domains are associated with a variety of maladaptive and prosocial traits and outcomes. So, are these domains really dark or light? Are narcissistic traits prosocial or toxic? Our assertion is that blanket categories cannot be applied to personality; that we can only understand how various aspects of personality relate to life outcomes at a more specified level. Recently, researchers (Christensen et al., 2020; Costantini et al., 2015; Elleman et al., 2020; Möttus & Rozgonjuk, 2019; Papageorgiou, Giannou, et al., 2019; Revelle et al., 2020; Seboth & Möttus, 2018) have argued that the use of broad personality factors is limiting. In the future, more can be gained from examining personality as an ecosystem, such as with network analysis, or in detail, through item or facet-level analyses. Others have identified lower-order facets of the Big Five through structural analyses, including openness (Christensen et al., 2019) and conscientiousness (MacCann et al., 2009; Roberts et al., 2005). The current study followed these guidelines, using novel network analytic techniques to delineate the lower-order structure of the DT, and to explore how these facets associate with one another in an ecosystem.

The EGA of DT facets highlights the need for a conceptualization and measurement of the DT that includes both vulnerable and grandiose narcissism. Extant literature has established Antagonism (vs. Agreeableness) as the common core of the DT (Vize et al., 2020). As this trait comprises both vulnerable and grandiose narcissism facets, DT assessments and models without a measure of vulnerable narcissism may be lacking. In terms of assessment, this is the first study to examine which facets of the DT are captured by the SD3 and DD, two of the most commonly used measures in DT research. Models of DT domains indicate that more comprehensive assessments of these domains should be used to examine personality-life outcome associations in research. If parsimonious measures are utilized, such as the SD3, DD, MACH-IV, and NPI, it is important to note which aspects of these domains are being assessed, as the current study has shown that many popular assessments do not capture all DT facets.



**Fig. 7.** A. EGA of MACH-IV, SD3, and DD Machiavellianism items with Sample 1. B. EGA of the four facet model with Sample 1. One factor was suggested. C. EGA of MACH-IV, SD3, and DD Machiavellianism items with Sample 2. Four facets were suggested in both samples. D. EGA of the four facet original model with Sample 2. One factor was suggested. CYN = Cynicism, DET = Detachment, MAN = Manipulation, MOR = Morality.

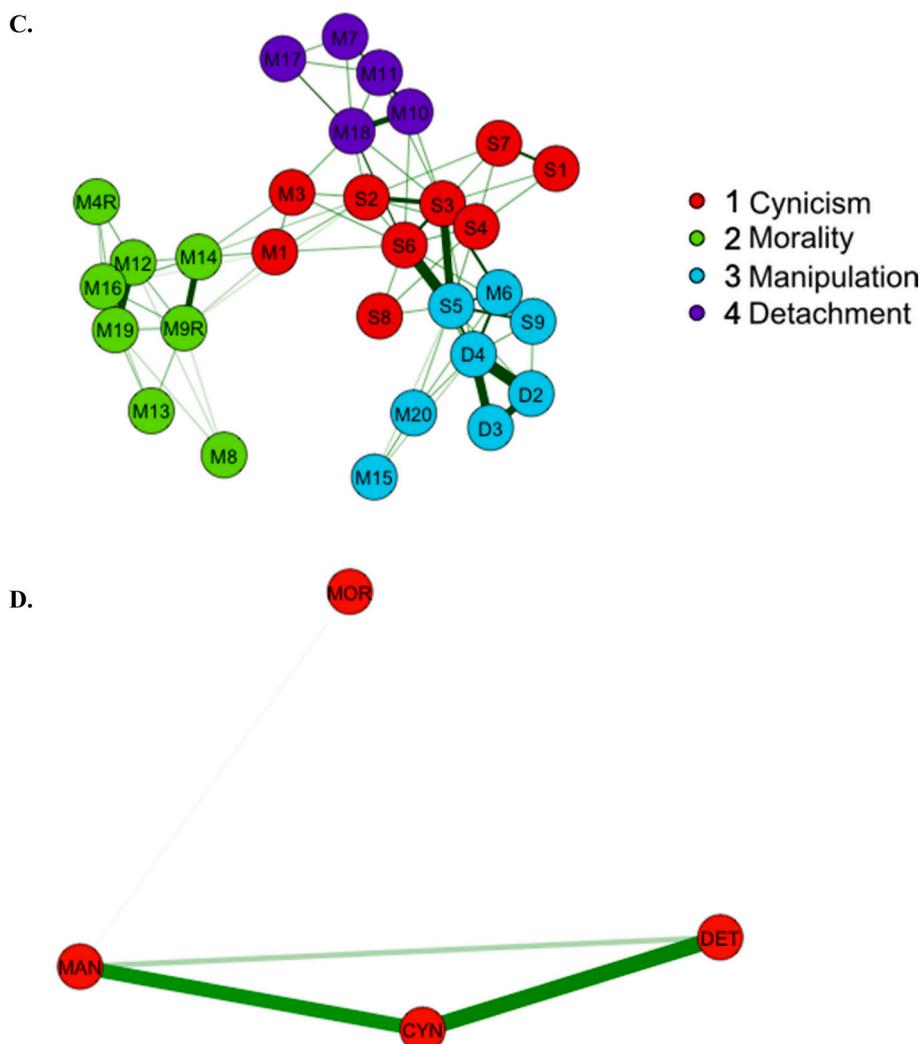


Fig. 7. (continued).

#### 4.4. Limitations and future directions

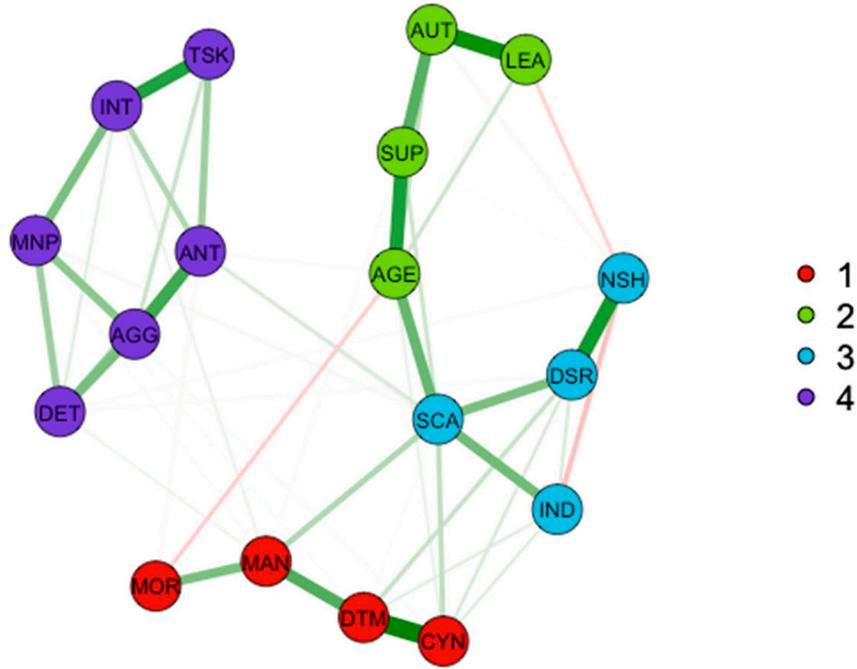
Although this study had a number of strengths, including a wide array of DT measures, use of novel statistical techniques, and item and facet-level analyses, there are several limitations. The main limitation of this study was sample size. Many of our models were complex, and therefore contain many nodes and edges. It is possible that differences in model structures between both samples are due to sample size. To compensate for this, regularization techniques were applied to networks (Epskamp et al., 2018), redundant items were removed, and EGA models were cross-validated in two samples. Golino and Epskamp (2017) found that EGA performs very well with sample sizes of 500 on models that have 4 factors (90% accuracy). As our models generally contained more than four facets, except for Machiavellianism, we chose to apply stricter validation methods by using two independent samples (total  $N = 525$ ) and replicating initial models (Picard & Cook, 1984). Future research should extend these findings by applying EGA to a larger pool of DT items.

Our samples mostly consisted of MTurk participants. However, MTurk can provide efficient, high-quality samples (Miller, Crowe, et al., 2017). Use of only self-report measures is a limitation, as responses may be influenced by common-method variance (Podsakoff et al., 2003). We ran several data quality checks for inattention, insufficient response time, and acquiescent responding, ensuring final samples included reliable responses. This led to removing a substantial proportion of the

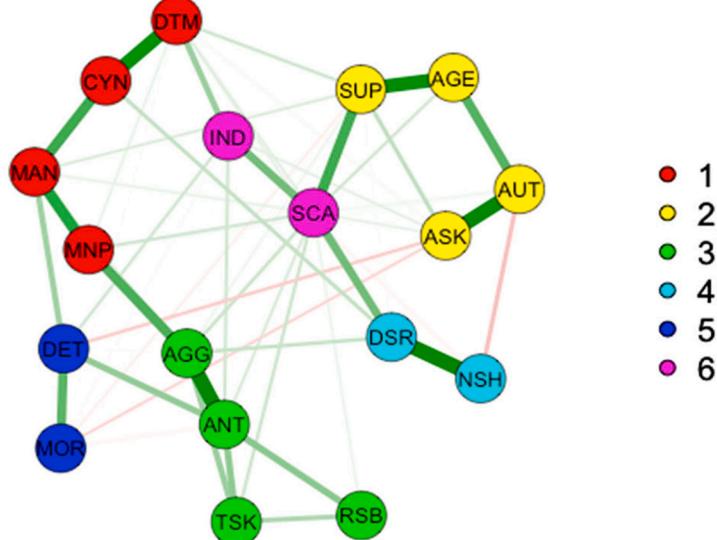
original sample. Therefore, models from Sample 1 were replicated with a larger portion of the sample and correlated to test for similarity. All networks showed moderate to strong correlations with the larger sample (see Section V of Supplementary Material for further information). Networks obtained with the trimmed sample ( $N = 301$ ) were less influenced by method effects (Lindwall et al., 2012), and identified facets more consistent with theoretical descriptions of the DT.

As we chose to assess the dimensionality of the DT, we did not include an exhaustive number of trait-specific measurements. For example, we did not include a specific measure of vulnerable narcissism. Despite this, our work aligns with previous findings on the dimensionality of narcissism (Crowe et al., 2019; Krizan & Herlache, 2018; Miller, Lynam, et al., 2017). We also did not include more than one trait-specific measure of Machiavellianism or Psychopathy. Prior research has applied factor analytic techniques to narcissism (Crowe et al., 2019) and psychopathy (Collison et al., 2020), and found similar results. This provides new support for the viability of EGA as a dimension reduction technique in personality research, which so far has only been tested with Openness to Experience at the item level (Christensen et al., 2019) and the DT at the factor level (Trahair et al., 2020). Tests of EGA have shown that the TMFG method performed similarly to parallel analysis, which is one of the most robust traditional techniques (Golino et al., 2020).

In conclusion, these findings both support and expand previous research on the structure of DT domains. Antagonism connects not only grandiose and vulnerable narcissism, but the DT cluster as a whole. The

**A.**

**Fig. 8.** A. EGA of DT facets with Sample 1. Four factors were suggested. B. EGA of DT facets with Sample 2. Six factors were suggested. AGE = Agentic Extraversion, AGG = Aggression/Impulsivity, ANT = Antisocial psychopathy, ASK = Acclaim-seeking, AUT = Authority, CYN = Cynicism, DET = Detachment (Psych), DSR = Distrustful Self-reliance, DTM = Detachment (Mach), IND = Indifference, INT = Interpersonal psychopathy, LEA = Leadership, MAN = Manipulation (Mach), MNP = Manipulation (Psych), MOR = Morality, NSH = Narcissistic Shame, RSB = Risky Behavior, SCA = Self-centered Antagonism, SUP = Superiority, TSK = Thrill-seeking.

**B.**

**Table 4**  
Facets derived from the EGA of Machiavellianism.

Facet label	Example item	Reliability
Sample 1 ( $N = 301$ )		
Facet 1	Manipulation	"I have used deceit or lied to get my way"
Facet 2	Morality	"Most people are basically good and kind" (reversed)
Facet 3	Detachment	"It's not wise to tell your secrets"
Facet 4	Cynicism	"Generally speaking, people won't work hard unless they have to"
Sample 2 ( $N = 224$ )		
Facet 1	Cynicism	"Generally speaking, people won't work hard unless they have to"
Facet 2	Morality	"Most people are basically good and kind" (reversed)
Facet 3	Manipulation	"I have used deceit or lied to get my way"
Facet 4	Detachment	"Most people more easily forget the death of a parent than the loss of their property"

important role that facets play in linking domains together highlights the multidimensionality of personality, suggesting we must move beyond the factor models of super-traits. Exploring facet or even item-level associations between personality and life outcomes can provide new insights into the complexities of human nature.

#### CRediT authorship contribution statement

**Taylor E. Truhan:** Conceptualization, Writing - original draft, Writing - review & editing, Visualization, Formal analysis, Methodology, Investigation. **Paul Wilson:** Conceptualization, Writing - original draft, Writing - review & editing, Methodology. **René Möttus:** Writing - review & editing, Methodology, Formal analysis. **Kostas A. Papa-georgiou:** Conceptualization, Writing - original draft, Writing - review & editing, Methodology, Supervision.

#### Declaration of competing interest

All authors declare no conflicts of interest.

#### Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.paid.2020.110502>.

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