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# Mapping the manuals of madness: Comparing the ICD-10 and DSM-IV-TR using a network approach

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# Key words

ICD, DSM, network approach

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# Abstract

The International Classification of Diseases and Related Health Problems (ICD) and the Diagnostic and Statistical Manual of Mental Disorders (DSM) represent dominant approaches to diagnosis of mental disorders. However, it is unclear how these alternative systems relate to each other when taking into account the symptoms that make up the disorders. This study uses a network approach to investigate the overlap in structure between diagnostic networks pertaining to ICD-10 and DSM-IV-TR. Networks are constructed by representing individual symptoms as nodes, and connecting nodes whenever the corresponding symptoms feature as diagnostic criteria for the same mental disorder. Results indicate that, relative to the DSM-IV-TR network, the ICD-10 network contains (a) more nodes, (b) lower level of clustering, and (c) a higher level of connectivity. Both networks show features of a small world, and have similar (of "the same") high centrality nodes. Comparison to empirical data indicates that the DSM-IV-TR network structure follows comorbidity rates more closely than the ICD-10 network structure. We conclude that, despite their apparent likeness, ICD-10 and DSM-IV-TR harbour important structural differences, and that both may be improved by matching diagnostic categories more closely to empirically determined network structures. Copyright © 2016 John Wiley & Sons, Ltd.

# Introduction

At the end of the nineteenth century, scientists and government agencies became interested in gaining statistical knowledge of diseases (e.g. prevalence, comorbidity, and mortality rates). This led to the development of several classification systems, of which the International Classification of Diseases and Related Health Problems (ICD<sup>1</sup>, most recent version the 10th revision, ICD-10; World Health Organization (WHO),

<sup>1</sup> The abbreviations "ICD" and "DSM" are used to indicate the two different classification systems. Where specific versions of either are discussed, this will be indicated by adding the version number to the abbreviation.

1993) and the Diagnostic and Statistical Manual of Mental Disorders (DSM, most recent version DSM-5; American Psychiatric Association (APA), 2013a) arose as the current dominant frameworks for mental disorders, both in clinical applications and in scientific research.

Even though both manuals classify similar mental and behavioural disorders, research shows that the concordance between the two systems can differ dramatically across the range of disorders (Andrews *et al.*, 1999; Swift *et al.*, 2001). In particular, depression, dysthymia and substance dependence have a relatively high concordance (above 75%) while substance harmful use or abuse, post-traumatic stress disorder (PTSD) and agoraphobia without panic disorder fail to reach a 50% concordance.

Furthermore, although the prevalence of a disorder is roughly the same across the diagnostic manuals, patient populations identified by both manuals overlap only in part (Andrews et al., 1999; Tripp et al., 1998; Wetterling et al., 1996). For example, generalized anxiety disorder (GAD) patients, as diagnosed through DSM-IV, are more disabled by their mental disorder than GAD patients, as diagnosed through ICD-10 (Slade and Andrews, 2001). Research also indicates that such discrepancies are not always obtained. For example, notwithstanding differences in prevalence rates, ICD-10 and DSM-IV patients suffering from postconcussional disorder score alike on the outcome domains of psychiatric symptoms and disorders three months posttrauma (McCauley et al., 2005). Similar results were found by Pillmann et al. (2002) who investigated patients diagnosed with either acute and transient psychosis (ICD-10) or brief psychotic disorder (DSM-IV).

Characteristically, research comparing ICD and DSM focusses at the level of disorders (e.g. do disorder A of the ICD and disorder B of the DSM differ in respect to a certain measure). What is not taken into account is that these disorders are composite entities; they contain two or more symptoms that characterize the disorder. Regardless of which perspective one holds towards the relationship between disorder and its symptoms (Borsboom, 2008), symptoms are an essential part of identification and treatment of mental and behavioural disorders. This raises the question to what extent ICD and DSM are equivalently structured at the level of symptoms. This question has not been addressed in a systematic fashion, partly because no systematic methodology has been used for investigating relations between criteria that does not a priori assume the existence of discrete disorders or latent factors. In the present paper, we use such a methodology based on recent network approaches to the study of mental disorders (Cramer et al., 2010) and apply it to investigate the degree to which symptom structure of ICD and DSM overlap.

In network approaches to diagnostic systems, disorders are viewed as clusters of symptoms that form a network structure (Borsboom et al., 2011). One way to arrive at such a structure is by forming a so-called diagnostic network (Borsboom and Cramer, 2013). In such a network, symptoms are represented as nodes, and whenever symptoms function as criteria for the same disorder, the corresponding nodes are joined by an edge. Networks of distinct disorders may be connected to each other through shared symptoms (e.g. fatigue is a criterion in both major depressive disorder (MDD) and GAD, and therefore connects the networks of these two disorders). This has implications for the interpretation of comorbidity. Instead of comorbidity between MDD and GAD representing two disorder that are present at the same time, in a diagnostic network comorbidity is due to the (bi)directional relationship that MDD and GAD have through their shared symptoms (Cramer et al., 2010; see Figure 1). Similarly, symptoms that do not belong to the same diagnosis can still be connected indirectly, for example because there exists a third symptom that functions as a diagnostic criterion in both diagnoses. Through these patterns of direct and indirect connections, the symptoms in the diagnostic system form a network, which can be used to visualize the structure of the space of mental disorders as it is represented in a diagnostic system (Borsboom and Cramer, 2013). An example of such a network, which is represented in Figure 2 (right), is the DSM-IV-TR network constructed by Borsboom et al. (2011).

The representation of diagnostic systems as networks affords the possibility to study the structure of such systems systematically. In addition, this procedure allows for the possibility to compare networks based on different diagnostic systems in order to analyse the differences and communalities across such systems. The current paper takes advantage of this possibility to investigate the relation between ICD-10 (World Health Organization (WHO), 1992) and the DSM-IV-TR (American Psychiatric Association (APA), 2000). By representing each of these systems as diagnostic networks, we study the degree to which the two diagnostic manuals differ. This will be done by investigating measures of centrality describing symptoms' positions in a network relative to others and in relation to the complete network.

In addition, we investigate how both systems align with empirical data. In particular, we investigate whether Borsboom *et al.*'s (2011) finding that average distances between disorders in the DSM-IV-TR network correlate highly with empirical DSM-IV-TR comorbidity rates, generalizes to ICD-10. Finally, similarities in content between ICD-10 and DSM-IV-TR are identified. Due to exclusion criteria used in network construction, certain

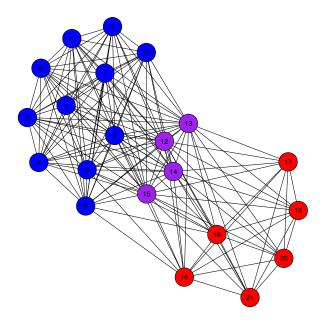


Figure 1. Visualization of a subset of DSM-IV-TR's criteria space, containing Major Depressive Disorder (MDD) and Generalized Anxiety Disorder (GAD). Criteria are represented as nodes and connected whenever they occur in the same disorder. Blue indicates MDD criteria; red indicates GAD criteria; purple indicates criteria that belong to both MDD and GAD. 1 = weight loss, 2 = worthlessness/guilt, 3 = depressed mood, 4 = diminished interest in activities, 5 = increased appetite, 6 = weight gain, 7 = decreases appetite, 8 = psychomotor retardation, 9 = thoughts of death, 10 = 2 or more Major Depressive Episodes, 11 = hypersomnia, 12 = fatigue, 13 = decreased concentration, 14 = insomnia, 15 = psychomotor agitation, 16 = irritability, 17 = excessive worry, 18 = excessive anxiety, 19 = difficulty controlling worry, 20 = mind going blank, 21 = muscle tension.

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disorders will no longer be distinguishable from other disorders. For example, after applying the exclusion criteria, no distinction can be made between ICD-10's acute polymorphic psychotic disorder with symptoms of schizophrenia (F23.1) and undifferentiated schizophrenia (F20.3). Therefore, not all disorders that occur in the manuals will be present in the networks. Determining which disorders occur in both networks identifies those that function as the common ground to both systems, which may provide useful information to scholars involved in forming in future editions of ICD and DSM.

#### Methods

Because our aim is to compare ICD and DSM networks, we took care to minimize methodological differences in the construction of the networks. Since the DSM-IV-TR network has already been constructed by Borsboom *et al.* (2011), we follow their network construction procedure as closely as possible.

For the ICD network, each criterion of ICD-10 +Classification of Mental and Behavioural Disorders (World Health Organization (WHO), 1993) was represented as a node. In keeping with Borsboom *et al.*'s (2011) procedure, criteria that contain causal, temporal, or exclusion features, or deal with interferences with daily living or intact abilities, were excluded.

Diagnostic criteria do not map onto symptoms uniquely, because some criteria are defined as disjunctions of symptoms. Disjunctive criteria were separated into their constituent parts (e.g. *increased activity or physical restlessness* was decomposed into two connected nodes). Sometimes, criteria are formulated differently but can still be considered equivalent for present purposes (e.g. *hyperactivity* and



**Figure 2.** Visualization of the ICD-10 (left) and DSM-IV-TR (right) criteria space. Criteria are represented as nodes and connected whenever they occur in the same disorder. Colour of nodes (middle) signifies the disorder class in which they occur most often. The DSM-IV-TR criteria space is from "The Small World of Psychopathology" by D. Borsboom, A. O. J. Cramer, V. D. Schmittmann, S. Epskamp, and L. J. Waldorp, 2011, Plos ONE, 6, p. 3. Adapted with permission.

increased activity were considered the same node). Because it is not always clear-cut whether two or more criteria are equivalent, all criteria were initially categorized as (a) unique, (b) potentially equivalent to other criteria, or (c) definitely equivalent to other criteria. Criteria were classified as unique if they occur in only one disorder and are not potentially equal to other criteria (e.g. paralysis in postencephalitic syndrome is a unique criterion). Criteria were classified as *definitely equivalent* if they were literally identical (e.g. difficulty in concentrating is a symptom in manic episode as well as GAD). Finally, all potentially equivalent criteria (19% of the remaining symptoms) were listed and subsequently judged by the authors of this paper as to whether they are similar enough that they are unlikely to be behaviourally distinguishable. Consensus was reached for all criteria under discussion (a detailed report on this can be requested from the first author). The ICD network was then constructed by connecting criteria listed for the same disorder with an edge.

The ICD-10 contains 321 disorders and 947 criteria. After accounting for overlap in criteria, the ICD-10 network contains 153 disorders, 589 nodes, and 23,525 edges. Although the DSM-IV-TR network (Borsboom et al., 2011) has a similar number of disorders (148) it has only 439 nodes and 2626 edges. The striking difference in number of edges can largely be attributed to the presence of three ICD-10 disorders in the ICD-10 network: adjustment disorder (F43.2), depressive conduct disorder (F92.0), and other mixed disorders of conduct and emotions (F92.8). Compared to the other disorders of ICD-10, these three disorders differ in the way their criteria list is established. It is not unusual for disorders to refer to the criteria of other disorders (e.g. recurrent depressive disorder includes the criteria of mild depressive episode). Typically, however, such referrals are limited to disorders within the same chapter (e.g. an affective disorder in chapter F30-39 refers to other affective disorders in the same chapter) or to a few disorders from a different chapter (e.g. schizoaffective disorders in chapter F20-29 refers to several affective disorders in chapter F30-39). However, adjustment disorder, depressive conduct disorder and other mixed disorders of conduct and emotions refer to complete chapters other than their own. None of the DSM-IV-TR (American Psychiatric Association (APA), 2000) disorders have this characteristic. This makes a fair comparison between the ICD-10 and DSM-IV-TR networks problematic, as the entire network structure of ICD-10 becomes dominated by the three superclusters generated by these disorders. To remove this inequality, these disorders were excluded from the ICD-10 network. This resulted in a network containing 150 disorders, 588 nodes, and 6169 edges.

## Analyses

Properties of the ICD-10 network and its giant component were calculated and compared to those of the DSM-IV-TR network as reported by Borsboom et al. (2011). We give a short overview of the network properties we investigated. Node *degree* is a measure of centrality defined as the total number of direct neighbours a given node has. The shortest path length between two nodes is the number of nodes that lie on the shortest path that connects these nodes, and the average shortest path  $length^2$  is a measure of how well connected a network is. Connectivity is a measure of the robustness of the network; the more tightly connected a network is, the more nodes have to be removed to disconnect the remaining nodes. Clustering however indicates the ratio between the amount of edges within and between clusters, and is indicated by the *transitivity*<sup>3</sup> of a network. Average shortest path length and transitivity can be used to calculate the small-world-ness index (Humphries and Gurney, 2008). If a network scores above three on this index, indicating a small world structure, it has a similar average shortest path length, but a higher level of clustering, as compared to a network of the same dimensions, in which the same number of edges is assigned to node pairs completely at random (see Watts and Strogatz, 1998). In the MDD-GAD network (Figure1), the shared symptoms fatigue, poor concentration, insomnia, and restlessness have the highest degree, indicating that these four symptoms have the most connections to other symptoms. The average shortest path between MDD and GAD is very short because the shared symptoms make travelling from one MDD symptom to one GAD symptom very easy. Therefore, the MDD-GAD network could be considered highly connected. However, because of the shared symptoms the transitivity of this network is low, indicating low clustering. Because of this, the MDD-GAD network does not show a small-world structure.

Lastly, a network may contain a *giant component*: a large, constant fraction of the total network. Having a *giant component* implies that there are nodes (e.g. symptoms) that are not connected to a large portion of network, and are thus not influenced by any characteristics of or activity in this giant component. Networks were

<sup>&</sup>lt;sup>2</sup> The average shortest path length *L* is the average over the shortest path lengths l(i,j) of all node pairs.

<sup>&</sup>lt;sup>3</sup> Transitivity is based on triplets of nodes. A triplet consists of three nodes that are connected by either two (open triplet) or three (closed triplet) edges. Transitivity is the number of closed triplets over the total number of triplets (both open and closed).

visualized using the R-package *qgraph* version 1.3 (Epskamp *et al.*, 2012).

To investigate whether features of the network structures of ICD-10 and DSM-IV-TR correspond to the structure of empirical data, the average shortest path lengths between disorders were correlated with their respective comorbidity rates. The hypothesis tested in this comparison is that comorbidity arises from the fact that symptoms of disorders are directly and indirectly connected within the network structure. In case of the MDD-GAD network (Figure 1) this would imply that a high comorbidity rate between the two disorders is due to their short average shortest paths. Hence, the more direct connections exist between symptoms of disorders (i.e. average shortest path-length), the higher the expected comorbidity rate. For this analysis, we used findings of Slade and Watson (2006), who reported ICD-10 and DSM-IV-TR comorbidity rates of 11 disorders: MDD<sup>4</sup>, dysthymia, GAD, PTSD, social phobia, panic disorder, agoraphobia, obsessive-compulsive disorder, alcohol dependence, drug dependence, and neurasthenia. To calculate average shortest path lengths, it is necessary that the disorders are connected to each other, e.g. are part of the giant component.

Although such analysis has been done before for the DSM-IV-TR by Borsboom *et al.* (2011) using the data from Krueger (1999), here we use the data from Slade and Watson (2006) for two reasons. First, using data collected by the same researchers reduces biases in comparing the relationship between the ICD network and comorbidity rates with the relationship between DSM network and comorbidity rates. Second, using other data than that from Krueger (1999) provides the opportunity to replicate the findings by Borsboom *et al.* (2011).

To investigate *common ground* between the two diagnostic manuals, we specifically studied those disorders that were present in both the DSM-IV and ICD-10 network. Equivalence between disorders of DSM-IV and ICD-10 was determined according to the DSM-IV-TR (American Psychiatric Association (APA), 2000), which for each disorder gives both a DSM-IV-TR and ICD-10 code. If a disorder from one network is equal to a disorder from the other network (e.g. dysthymic disorder from the DSM-IV-TR network and dysthymia from the ICD-10

network) this disorder was categorized as belonging to the common ground.

# Results

# ICD network structure properties

Figure 2 (left) shows a visual representation of the ICD-10 network, and Table 1 lists its global properties (number of nodes and edges, transitivity, average degree, average shortest path length) alongside those of the DSM-IV-TR network. The ICD-10 network contains more nodes and edges than the DSM-IV-TR network, despite the fact that both networks contain roughly the same number of disorders. The DSM-IV-TR network has a higher transitivity and a lower average shortest path length than the ICD-10 network, indicating that the DSM-IV-TR network is more tightly clustered than the ICD-10 network. The ICD-10 network however has a higher average degree, which together with the larger giant component and higher average shortest path length indicates that the ICD-10 network has a higher level of connectivity than the DSM-IV-TR network. These findings are probably the result of the fact that the ICD-10 contains more criteria, more criteria per disorder, and more criteria that are present in multiple disorders than DSM-IV-TR. The DSM-IV-TR network contains more

**Table 1.** Network properties of the ICD-10 and the DSM-IV-TR network graph

	ICD-10	DSM-IV-TR
Global properties		
Number of disorders	150	148
Number of nodes	588	439
Number of edges	6169	2626
Number of components	58	66
Average degree	20.98	11.96
Average shortest path length	3.40	2.55
Transitivity	0.60	0.71
Giant component properties		
Small world index	6.73	6.20
Number of disorders	84	69
Contains % of all disorders	56.00	46.62
Number of nodes	454	208
Contains % of all nodes	77.21	47.38
Number of edges	5913	1949
Contains % of all edges	95.85	74.23
Average degree	26.05	18.74
Average shortest path length	3.41	2.60
Transitivity	0.60	0.68

<sup>&</sup>lt;sup>4</sup> Major depression covers all different depressive episodes (mild, moderate, severe with and without psychotic symptoms) listed in the ICD-10 (T. Slade, personal communication, 29 April 2014). Severe depressive episode with psychotic symptoms (F32.3) contains all other depressive episode diagnoses and as such was chosen as the network equivalent of major depression.

components than the ICD-10 network, although this difference is small.

Of all the disorders present in the networks, 110 disorders (73%) of ICD-10 were judged by APA (2000) as to be the equivalent of 111 disorders (75%) of DSM-IV-TR. These common ground disorders include large parts of the mood, anxiety, childhood and adolescence, personality, eating, and schizophrenia-related disorders.

As is evident from Figure 2, the ICD-10 network features a giant component. This component contains 56% of all disorders, 77% of all nodes, and more than 96% of all edges. In comparison, the DSM-IV-TR giant component contains 47% of all disorders, 47% of all nodes, and 74% of all edges of the complete DSM-IV-TR network. The ICD-10 giant component contains twice as many nodes and three times as many edges as the DSM-IV-TR giant component. Given that the ICD-10 and DSM-IV-TR networks contain the same number of disorders, it follows that ICD-10 disorders contain more symptoms and more symptoms feature in multiple disorders than in DSM-IV-TR.

Similar to the overall network, the average degree and the average shortest path length are higher within the ICD-10 giant component, while the transitivity is higher in DSM-IV-TR giant component. The small world index of both giant components exceeds the small-world-ness criterion of three (Humphries and Gurney, 2008).

Table 2 shows the nodes of the ICD-10 and the DSM-IV-TR networks with the highest degrees (e.g. total number of connected neighbours of a node). Interestingly, the two manuals share five nodes in this top 10, with insomnia at the top as the most connected node in both

 Table 2. Top 10 criteria with the highest degree for ICD-10

 and DSM-IV-TR network

	ICD-10	DSM-IV-TR
1	Insomnia <sup>1</sup>	Insomnia <sup>1</sup>
2	Irritability <sup>1</sup>	Psychomotor agitation
3	Apathy	Psychomotor retardation <sup>1</sup>
4	Difficulty in concentrating <sup>1</sup>	Depressed
5	Nausea	Accelerated heart rate
6	Emotional liability	Distractibility
7	Sweating <sup>1</sup>	Irritability <sup>1</sup>
8	Chest pain	Anxiety and Hypersomnia
9	Restless sleep	Sweating <sup>1</sup> and Weight loss
	-	Difficulty in concentrating <sup>1</sup>
10	Psychomotor retardation <sup>1</sup>	and Hallucinations/illusions

<sup>1</sup>Criteria that occur in the top 10 of both networks. Places 8 through 10 in the DSM-IV-TR hold multiple symptoms.

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networks. This implies that insomnia is the most featured symptom in both networks. Thus, at this level, the diagnostic systems show important similarity.

#### Comparing the ICD network to ICD comorbidity rates

To compare the network structure to the structure of empirical data, the average shortest path lengths between combinations of disorders were correlated with the empirical comorbidity rates between the corresponding diagnoses. Except for obsessive-compulsive disorder and alcohol and drug dependence, all previously mentioned disorders from Slade and Watson (2006) are included in the giant component of the ICD-10 network, and are as such suitable for calculating the average shortest path lengths.

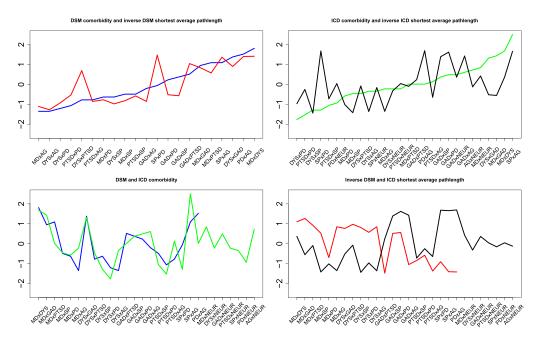
Figure 3 (top right) shows the standardized comorbidity rates of and the standardized average shortest path lengths between the combinations of remaining ICD-10 disorders. The correlation between the average shortest path length and comorbidity rate is -0.39, indicating a moderate negative relationship. This means that the smaller the distance between two disorders is in the ICD-10 network, the higher the observed empirical comorbidity is. Four combinations of disorders deviate particularly strongly from this overall pattern: under the assumption of a network structure, the average shortest path lengths between social phobia and panic disorder, and between agoraphobia and panic disorder, are lower than one might expect from their comorbidity rates. In contrast, average shortest path lengths between GAD and dysthymia, and between GAD and MDD, are much higher than one would expect from their comorbidity rates.

## Comparing DSM network to DSM comorbidity rates

For comparison, we executed the same analysis for DSM-IV-TR. Except for neurasthenia<sup>5</sup>, obsessive-compulsive disorder and alcohol and drug dependence, all previously mentioned disorders are included in the giant component of the DSM-IV-TR network, and are as such suitable for calculating the average shortest path lengths. Using the DSM-IV-TR network by Borsboom *et al.* (2011), the average shortest path lengths for the different combinations of these disorders were calculated and correlated to the empirical comorbidity rates.

Figure 3 (top left) shows standardized comorbidity rates and standardized average shortest path lengths for all combinations of the remaining DSM-IV-TR disorders.

<sup>&</sup>lt;sup>5</sup> The diagnosis neurasthenia is not defined in the DSM-IV-TR.



**Figure 3.** The relationship between the standardized comorbidity rates and standardized average shortest path lengths of the ICD-10 and the DSM-IV-TR. Red = inverse standardized DSM-IV-TR average shortest path length, blue = standardized DSM-IV-TR comorbidity rates, black = inverse standardized ICD-10 average shortest path length, green = standardized ICD-10 comorbidity rates. DYS = dysthymia, PD = panic disorder, PTSD = post-traumatic stress disorder, SP = social phobias, NEUR = neurasthenia, MD = major depression, AG = agoraphobia, GAD = generalized anxiety disorder. No results for neurasthenia are given for the DSM-IV-TR because this diagnosis is not part of DSM-IV-TR manual.

The correlation between DSM-IV-TR comorbidity rates and average shortest path lengths is -0.80, replicating the strong negative relationship found by Borsboom et al. (2011). This means that the smaller the distance between two disorders is in the ICD-10 network, the higher the observed empirical comorbidity is. An example of this finding is the combination MDD-GAD. It is notable that, under the assumption of a network structure, the average shortest path length between social phobia and panic disorder, and dysthymia and PTSD is smaller than expected based on their comorbidity rates. Interestingly, the smaller than expected average shortest path length between social phobia and panic disorder also appeared in the comparison of ICD-10 comorbidity rates and average shortest path lengths. However, the average shortest path length between GAD and either social phobia or panic disorder is higher than is expected based on their comorbidity rates.

## Comparing ICD to DSM

The correlation between standardized empirical comorbidity rates for pairs of disorders, as diagnosed according to ICD-10 and according to DSM-IV-TR

Int. J. Methods Psychiatr. Res. (2016). DOI: 10.1002/mpr Copyright © 2016 John Wiley & Sons, Ltd. (Figure 3, bottom left), equals 0.72. This indicates that the actual diagnoses, though collected using instruments based on different diagnostic systems, cluster in similar ways. In contrast, the correlation between the standardized average shortest path lengths of the ICD-10 and DSM-IV-TR networks (Figure 3, bottom right) equals 0.42. Thus, the similarity between the empirical comorbidity patters generated by the diagnostic systems exceeds the similarity between the network-structure of the diagnostic systems.

## Discussion

In this paper we examined similarities and differences in the structure of ICD-10 Classification of Mental and Behavioural Disorder and DSM-IV-TR using a network approach. Both ICD-10 and DSM-IV-TR networks are characterized by a small-world structure, indicating that, compared to a network in which the same number of nodes is connected by the same number of edges in a completely random fashion (a random graph), both the ICD-10 and DSM-IV-TR networks have similar short path lengths between criteria but a much higher level of clustering. This increased clustering combined with the short distances between the criteria implies that once a

criterion is "active", this activity may spread relatively quickly over the nodes in the network (Watts and Strogatz, 1998). For the diagnostic networks, this indicates that suffering from one symptom (e.g. insomnia) implies an increased risk of suffering from other symptoms that are (in)directly connected to the first symptom (e.g. restlessness) and thus increases the chance of comorbidity.

Additionally, for both diagnostic manuals, the average shortest path lengths between disorders in the network was negatively correlated to the comorbidity rates of disorders. Thus, the shorter the network distance between disorders, the higher their comorbidity. This is a conceptual replication of the finding by Borsboom *et al.* (2011).

Traditional approaches seek the explanation of these comorbidity patterns in the postulation of one or more latent variables that underlie symptom covariation (e.g. Krueger, 1999; Caspi *et al.*, 2014), possibly rooted in the overlap of genetic determinants (Mineka *et al.*, 1998). Network approaches do not assume the presence of a latent variable, and instead explain comorbidity in terms of spreading symptom activation, by which symptoms in one part of the network can affect (in)directly connected symptoms. For example, insomnia may serve to channel activity in one subnetwork (e.g. MDD) to another (e.g. GAD) because it plays a role in both (Cramer *et al.*, 2010).

Current data do not allow the resolution of which of these explanations is correct. However, the network analyses put forward here do suggest that so-called nonspecific symptoms (which feature as criteria for multiple disorders) may be crucial in understanding patterns of comorbidity. The current analysis shows that several non-specific symptoms, such as insomnia and irritability, are highly central in both the ICD-10 and DSM-IV-TR network structures; thus, although there are many differences in the precise allocation of symptoms to disorders in these diagnostic systems, they do agree on the pervasiveness and centrality of non-specific symptoms. In our view, the function of these symptoms in sustaining and transferring mental health problems should be the focus of research activities. In particular, future research should be directed towards the question of whether nonspecific symptoms are causally active in promoting comorbidity, as the network theory holds, or merely reflect yet another effect of a latent variable (Cramer et al., 2010).

The ICD-10 giant component has twice as many symptoms and is also more tightly connected than the DSM-IV-TR giant component. It appears that ICD-10 contains many symptoms that feature in multiple disorders, implying that the ICD-10 committees may have Tio *et al.* 

been less strictly selecting criteria on the basis of their specificity for a certain syndrome.

Under the assumption that the data are in fact generated through a network structure (e.g. through an Ising model; van Borkulo et al., 2014), we find that the DSM-IV-TR network reflects the empirical comorbidity rates (Slade and Watson, 2006) more closely than the ICD-10 network. Because the disorders that were used in these calculations do not differ much between the two manuals (American Psychiatric Association (APA), 2000), the source of this discrepancy must lie in differences in the way the systems associate symptoms and disorders. A theoretically interesting possibility is that ICD-10 underrepresents the degree to which mental disorders are in fact structured (i.e. ICD-10 is more liberal is assigning symptoms to a disorder than DSM-IV-TR, thereby making the boundaries between disorders "fuzzy"). This would align with the finding that the ICD-10 network features a lower level of clustering, and with the finding that the comorbidity data gathered with both DSM-IV and ICD-10 show larger concordance to each other than the diagnostic systems themselves.

It must be emphasized that the networks do not represent the complete DSM-IV-TR and ICD-10. Due to current restrains on network construction methods information such as causal, temporal, contextual, or exclusion features cannot yet be incorporated. The same is true for the distinction between "essential" and "normal" symptoms (e.g. the distinction between depressed mood and insomnia in MDD). Being able to include such criteria greatly improves the validity of the network as a representation of diagnostic manuals.

Digging into the content of the networks, we find that approximately 74% of the disorders in the ICD-10 and DSM-IV-TR network are present in both networks. This is in line with First's (2009) conclusion that 78% of all disorders in ICD-10 and DSM-IV are conceptually equivalent. However, conceptual differences, as identified by First (2009), often involve casual (depressive episode), temporal (schizophrenia), and priority (agoraphobia) criteria for disorders. In our study, however, these and other features have been removed from the criteria pool during network construction and can therefore not contribute to differences between disorders. It is therefore expected that the concordance between the ICD-10 and DSM-IV-TR in our study should be equal to or higher than the concordance found by First (2009). Since the removal of contextual criteria does not increase the concordance between ICD-10 and DSM-IV-TR, the question what makes the ICD-10 and DSM-IV-TR differ remains. Instead of comparing the diagnostic manuals at the

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disorder level, investigating the equivalence of individual symptoms (e.g. is hypersomnia as described in ICD-10 the same as hypersomnia as described in DSM-IV-TR) might shed some light on this.

Although ICD and DSM were developed with different goals and audiences in mind (American Psychological Association, 2009), the WHO and the APA have collaborated on several occasions during the revisions of these diagnostic system (World Health Organization (WHO), 2008). This raises the question why the two diagnostic systems still contain such important structural differences. One possible explanation is that ICD-10 and DSM-IV-TR may contain residual differences that stem from their respective origins in ICD-6 (World Health Organization (WHO), 1949) and the DSM-III (American Psychiatric Association (APA), 1980). To get a better understanding of this process, future research may construct networks of the previous versions of ICD and DSM to visualize and analyse their development over time by using the method demonstrated here.

The same holds for future developments. The WHO is still working on the ICD-11, which is due in 2018 (World Health Organization (WHO), 2015); the APA already published their newest version of the DSM, the DSM-5 (American Psychiatric Association (APA), 2013a). All these alterations, may change the network structure of and overlapping content between the manuals. It is important that our network structures are constructed only with help of diagnostic criteria. It is therefore to be expected that only changes on the criteria level will

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influence the network structure of the manual; renaming or re-categorizing disorders does not. This means that the additional symptoms to PTSD, the introduction of autism spectrum and new depressive disorders, the elimination of schizophrenia subtypes, and the updated criteria in delirium and motor disorder (American Psychiatric Association (APA), 2013b) will be reflected in differences between the DSM-IV and DSM-5 network structure. However, moving obsessivecompulsive disorder from the chapter anxiety disorders to the chapter obsessive-compulsive and related disorders is expected to have little to no effect on the network structure of the DSM-5.

It would be interesting to investigate whether these revised network structures correlate higher with the structure of empirical data (e.g. comorbidity rates). In addition, network analyses may be used to guide changes in the construction of diagnostic systems. For example, it is straightforward to compute whether a projected change of symptom allocation in, say, ICD-10, will lead to an increased or decreased similarity of the resulting network to the DSM or to an empirical diagnostic network.

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# **Declaration of interest statement**

The authors have no competing interests.

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