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Repetitive Behaviors in Autism and Obsessive–Compulsive Disorder: New Perspectives from a Network Analysis

Laura Ruzzano · Denny Borsboom · Hilde M. Geurts

Abstract The association between autism and obsessive–compulsive disorder (OCD) seems largely dependent upon observed similarities in the repetitive behaviors that manifest in both disorders. The aim of this study was to use a network approach to explore the interactions between these behaviors. We constructed a network based on clinician's perceptions as well as a network based on 213 clinically diagnosed children. In all networks, autism and OCD emerged as two distinct symptom clusters and obsessions and compulsions showed few direct associations with autism symptoms. Further, sensory interests were identified as behaviors that may contribute to the link between autism and OCD. Through network analysis, we expose the symptom pathways that may lead to the perceived association between autism and OCD.

Keywords Autism · Obsessive–compulsive disorder · OCD · Repetitive behaviors · Network analysis

L. Ruzzano · H. M. Geurts
Research and Development, Dr. Leo Kannerhuis, Center for Autism, Amsterdam, The Netherlands

L. Ruzzano (✉) · H. M. Geurts
Dutch Autism and ADHD Research Center (d'Arc), University of Amsterdam, Weesperplein 4, 1018 XA Amsterdam, The Netherlands
e-mail: LRuzzano@gmail.com

D. Borsboom · H. M. Geurts
Department of Psychology, University of Amsterdam, Amsterdam, The Netherlands

H. M. Geurts
Cognitive Science Center Amsterdam, University of Amsterdam, Amsterdam, The Netherlands

Introduction

Restricted and repetitive behaviors were among the original features documented in autism (Kanner 1943). These form a broad class of behaviors, some of which show considerable resemblance to other disorders (Esbensen et al. 2009; Lam et al. 2008; Leekam et al. 2011) and may be contributing to the elevated rates of comorbidity among autism populations (Mazefsky et al. 2012). In response, recent efforts have been directed towards unravelling the nature of the relationship between autism and associated disorders. This study contributes to these efforts by examining the interactions between the repetitive behaviors characteristic of autism and obsessive–compulsive disorder (OCD). To do so, we apply the network approach to psychopathologies, which conceptualizes disorders as mere labels for a system of causally connected symptoms (Borsboom and Cramer 2013). Our aim is to explore the utility of the network approach in understanding psychological disorders as well as to identify which repetitive behaviors interact in autism and compare this to OCD.

The network approach has emerged in response to the current conceptualization of a symptom as a measure of some causal latent disorder (Borsboom et al. 2011; Cramer et al. 2010). In contrast, the network perspective suggests that disorders emerge as highly connected clusters (e.g., networks) of symptoms, and that these clusters are created by direct interactions and causal influences between symptoms (Borsboom et al. 2011; Borsboom and Cramer 2013). In other words, if one symptom arises (e.g., concern with things touched due to dirt), that symptom is likely to cause other symptoms to arise (e.g., continue washing; Bringmann et al. 2013). While a single symptom may share many connections with other symptoms, these connections are not random and can vary in strength. Consequently,

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symptoms will cluster and share strong connections between symptoms associated with the same disorder, and fewer and weaker connections will be present between symptoms associated with different disorders (Borsboom et al. 2011). Thus, the network approach accounts for the statistical correlation often observed between symptoms of the same disorder.

In relation to autism and OCD, the network approach provides a framework through which we can assess whether autism and OCD represent two distinct but highly comorbid disorders (Bejerot 2007) or whether this is a potential case of symptom overlap (Bartz and Hollander 2006; Ivarsson and Melin 2008). Some suggest that the stereotyped and rigid behaviors observed in autism represent parallel behaviors to the obsessions and compulsion characteristic of OCD (Cath et al. 2008; Hollander et al. 2005; McDougle et al. 1995). For example, individuals with autism often insist on things being the same (Lam et al. 2008), such as an insistence on particular clothing, doing things at a particular time, or saying things in a particular way. These similarities continue to spur discussions about the association between autism and OCD.

Neurological findings have been another component stimulating the notion that symptom overlap may exist between autism and OCD. In autism, behaviors such as compulsive adherence to routines and stereotyped behaviors have been linked to differences in striatum development, and in particular caudate volume (Langen et al. 2009, 2011). Similarly, dysfunction in the caudate nucleus has also been associated with compulsions in OCD (Markarian et al. 2010). Such results imply that similar neural abnormalities may underlie the repetitive behaviors that appear alike in autism and OCD (South et al. 2005).

Others argue that despite these behavioral and neurological similarities, there exist meaningful differences between the actual repetitive behaviors seen in autism as compared to those in OCD. Indeed, individuals with autism have been found to have more compulsions than typically developing individuals (Ruta et al. 2010; Zandt et al. 2007). However, illustrative differences have also been reported. In comparison to those with OCD, individuals with autism have been consistently characterized by a lower overall frequency of OCD symptoms, symptom severity, and type based on content of OCD symptoms displayed (McDougle et al. 1995; Russell et al. 2005; Zandt et al. 2007). In particular, individuals with autism were less likely to endorse the most typical OCD symptoms: checking, washing, and counting. These differences have been attributed to the lack of obsessions found among individuals with autism (Lewin et al. 2011), as compared to the 95 % of individuals with OCD who show contextually associated obsessions and compulsions (Williams et al. 2011). As a result, many reason that the critical difference between autism and OCD depends on different interactions between their symptoms (Baron-Cohen 1989; Leonard and Riemann 2012; Williams et al. 2011).

The key to understanding the relationship between autism and OCD is to analyze whether there are convergent or divergent paths to these similar symptoms. For OCD, there is ample evidence to support a functional relationship between compulsions and obsessions (Markarian et al. 2010; Storch et al. 2008). That is, compulsions in OCD are maladaptive strategies used to cope with the perceived distress of the obsessions. The connection between obsessions and compulsions, based on content and emotional experience, both lack valid evidence among individuals with autism; some argue that this may be due to their difficulties in describing their mental states and experiences (Ruta et al. 2010; Weidle et al. 2012).

In contrast, it has been suggested that repetitive behaviors in autism may be a function of efforts to manage their unusual sensory processing (Baker et al. 2008). Reported sensory processing abnormalities among autism include hyper- and hypo-responsiveness and sensory overload (Leekam et al. 2011). Evidence supports that there is a significant relationship between sensory abnormalities (e.g., auditory, tactile, visual, low/high multisensory integration) and repetitive behaviors in autism (Boyd et al. 2009; Chen et al. 2009). However, the evidence for repetitive behaviors as coping mechanisms for sensory processing has been inconsistent (Rogers and Ozonoff 2005).

Thus, the discussion concerning repetitive behaviors in autism and their comparison to those observed in OCD parallels the central idea of the network approach: that psychological disorders are based on meaningful relations between symptoms. For this reason, the present paper employs network analysis to address this issue (Borsboom and Cramer 2013). The network analysis will allow us to identify which repetitive behaviors are connected, and characterize these connection based on the strength and frequency of the inter-symptom connections.

Methods

Study Design

Repetitive behaviors were analyzed in three networks: the Perceived Causal Clinician Network,[1] the Correlation Data

[1] The Perceived Causal Clinician Network is a direct representation of the causal relation between two symptoms as reported by the participating clinicians. Hence we denote this network the Perceived Causal Clinician Network.

Network and the Putative Causal Data Network.[2] To construct the Perceived Causal Clinician Network, we created the "Perceived Causal Relationship" scale (PCR, for details see measures section), a technique drawn from Frewen et al. (2011). The PCR scale was used to gain insight into the causal organization of the symptoms (Borsboom and Cramer 2013), as clinicians perceive it. Consequently, the Clinician Network based on the PCR scale helped aid our interpretation of the Data Network(s).

Association networks can be used as another way to explore, at first glance, the clustering of symptoms and the strength of a connection between specific symptoms, which can be suggestive of the underlying causal organization of symptoms (Borsboom and Cramer 2013). The Correlation Data Network was constructed based on an existing data set of children who had one or more clinical diagnoses. Correlations were calculated between repetitive behaviors and served as the input for the Correlation Data Network. From the Correlational Data Network, we derived the underlying skeleton for a putative causal network, which we denote as the Putative Causal Data Network.

The results from all three networks are then discussed together. We first review the interactions between autism symptoms and then the interactions between OCD symptoms. Due to the simple distinction between symptom type in OCD—obsession and compulsion—and because these symptoms are thought to causally influence each other (Markarian et al. 2010), we then discuss autism symptoms in relation to obsessive symptoms and in relation to compulsive symptoms characteristic of OCD.

Participants

Clinician Sample

Seven participating clinicians were recruited from various mental health settings in the Netherlands, ranging from private practice and specialized autism clinics to university based psychiatric hospitals. The clinicians were selected based on their specializations in the assessment and treatment of autism and/or OCD, and therefore served as trained raters in the PCR scale rating task. The average clinical experience with respect to each disorder was comparable for autism ($M = 15$, $SD = 8.2$) and OCD ($M = 17.7$, $SD = 12.3$, $p > .05$).

[2] The Putative Causal Data Network is an exploratory representation, of the hypothesized causal relationships that result in the structure of the Correlational Data Network. While these causal relations are based on a well-developed causal inference method for correlational data, we have denoted this network the Putative Causal Data Network in order to represent the exploratory nature of these results.

Data Sample

The data sample included 213 children, which have been previously analysed and described in various published articles (Geurts et al., 2004, 2008). Autism and OCD behaviors have not yet been analyzed in the manner of the present study. The children were between 5 and 14 years old ($M = 9.2$, $SD = 1.9$) and 86 % were male. All had an IQ above 80, as measured by the short version of the *Dutch Revised Wechsler Intelligence Scale for Children* (WISC-R; Haasen et al. 1986).

All children were from The Netherlands or Belgium, and met criteria for one or more of the following clinical diagnoses: autism (63 %), OCD (8 %), attention-deficit/hyperactivity disorder (ADHD; 54 %), Tourette syndrome (TS; 21 %), oppositional defiant disorder (ODD; 21 %), and conduct disorder (CD; 7 %). The proportion of children who met criteria for two or more clinical diagnoses was 55 %. Specialized multidisciplinary teams made the clinical diagnoses. These diagnoses were then verified through standardized assessment procedures (Autism Diagnostic Interview-Revised [ADI-R] and Diagnostic Interview Schedule for Children for DSM-IV, parent version [P-DISC-IV]; see Verté et al., 2006). Only those children that met the ADI-R criteria for autism, which is a score above 10 for social interactions, above 8 for language and communication, and above 3 for restricted and repetitive behaviors, and/or met the DISC-IV criteria for OCD, ADHD, TS, ODD or CD were included.

Although the sample includes children who met criteria for various yet related disorders, this does not necessarily hinder our analysis when applying the network approach. In a network approach, disorders are not causal factors that produce symptoms; instead, they are assumed to arise from tightly interacting sets of symptoms. Thus, the connection between any two symptoms occurs due to the autonomous interactive properties of those symptoms, and not because of an underlying disorder. To the extent that this is correct, diagnostic cases may be expected to exhibit stronger interactions between symptoms, but there is no a priori reason to expect that patterns of symptom interaction should be qualitatively different (although we cannot rule out this possibility). Thus, the general form of the network would be expected to remain stable.

Measures

ADI-R

The ADI-R is a standardized, semi-structured interview, which is administered to a child's primary caregiver by a trained interviewer. It contains 93 items and focuses on three domains of autistic symptomatology: (a) reciprocal

Table 1 Symptoms and centrality measures

Symptoms	Network labels	Clinician network			Data network	
		Out-degree	In-degree	Betweenness	Degree	Betweenness
Autism symptoms (ADI-R items)						
Circumscribed interests	CirInt	21.6	18.9	0	7.13	0
Unusual preoccupations	UnuPre	24.7	27.4	11.5	6.61	0
Repetitive use of objects or interests in parts of objects	RepObj	15.5	20.5	2	7.47	6
Compulsions and/or rituals	CompRit	29.1	29.7	40	8.61	12
Unusual sensory interests	SensInt	18.8	22.9	1	7.89	12
Complex mannerisms or stereotyped body movements	StMove	10.9	13.9	0	6.69	0
Stereotyped utterances/delayed echolalia	StUtter	10.8	15.1	1	7.50	0
Neologisms and/or idiosyncratic language	IdLang	9.2	12.2	0	5.93	0
Verbal rituals	VerbRit	15.0	14.5	6.5	8.15	10
OCD symptoms (P-DISC-IV items)						
Concern with things touched due to dirt/bacteria	ConDirt	18.9	16.9	0	6.01	2
Thoughts of doing something bad around others	ThoBad	16.6	16.1	0	4.84	0
Continual thoughts that do not go away	CntTho	28.3	23.7	13	6.70	4
Belief that someone/higher power put reoccurring thoughts in their head	HighTho	24.0	14.1	2	4.52	0
Continual washing	CntWash	16.9	17.3	0	4.34	0
Continual checking	CntCheck	18.8	17.6	0	6.11	2
Continual counting/repeating	RepCount	23.7	19.6	0	6.46	0
Repeatedly do things until it feels good or just right	RepDo	27.2	27.5	24	7.56	8

Centrality measures were computed with positive consideration for both the number of edges and edge widths ($\alpha = .05$)

social behavior; (b) communication and language; (c) restricted interests and stereotypic behavior (le Couteur et al. 1989; Lord et al. 1994). Items are scored on a 4-point scale: *no definite behavior of the type specified* (0), *behavior of the type specified probably present but not sufficiently severe or frequent enough to meet criteria for 2* (1), *definite abnormality in the specified behavior* (2), and *extreme severity of the specified behavior* (3). A child is diagnosed with autism when scores for each separate domain exceed the specified cutoff. For the restricted and stereotypic behaviors domain, only nine items are used to determine the cutoff algorithm. Only those nine items were used in present study.

To apply network analysis techniques, the data was re-coded so that a score of '0' remained 0, to represent the absence of abnormality. Scores of '1', '2', or '3' were re-coded as a 1, which indicated some abnormality in the specified behavior.

P-DISC-IV

The P-DISC-IV is a highly structured diagnostic interview, designed to assess psychiatric disorders (Ferdinand and van der Ende 2000; Shaffer et al. 2000). Only the obsessive–compulsive section was used, which consists of eight items (Table 1). In accordance with the P-DISC-IV algorithm, each item response that met the specified criteria of endorsement was coded '1', indicating abnormality in the specified behavior. Item responses that did not meet specified endorsement criteria were coded '0'.

PCR Scale

The PCR scale is a rating technique that is used to capture the cognitive perception of causal relations between two symptoms (Frewen et al. 2011). In the current study, the PCR scale was used to identify perceived causal relations between repetitive behaviors in autism and OCD, and the seven clinicians served as the raters in the PCR scale task. The PCR scale contained an aggregate of 17 items from the ADI-R and P-DISC-IV. Clinicians were asked about each two directional formulation of symptom pairs, in which each pair of symptoms served as an item on the rating scale. For example, clinicians had to indicate whether they believed "concern with things touched due to dirt or bacteria" directly caused "continual washing", as well as whether "continual washing" directly caused "concern with things touched due to dirt or bacteria." The presentation of autism and OCD symptoms were intermixed, and

the clinicians were not informed which symptoms were from autism versus OCD or about the nature of the study. This resulted in 272 possible causal relations to be rated. The PCR scale was made using the online survey software *Qualtrics*©.

Network Construction

To construct symptom networks for OCD and autism, each symptom is represented by a *node*, and each connection between two nodes as an *edge* (Borsboom and Cramer 2013). In the present case, the relevant node set is the set of symptoms that are part of OCD, autism, or both. The set of edges connecting these nodes were determined either by causal-effect ratings from the PCR scale (Perceived Causal Clinician Network) or through analysis of the empirical data (Correlation Data Network and Putative Causal Data Network). Note that, in the network approach, an edge represents a direct relationship between two symptoms. A directed edge (arrow) between two nodes indicates a (reported or hypothesized) causal relation, whereas an undirected edge indicates correlations (in the Correlation Data Network) or conditional dependencies (in the Putative Causal Data Network).

Analyses

Clinician Network

For each item on the PCR scale, the total number of causal relations indicated by the clinicians was recorded to create an adjacency matrix. Each value in the adjacency matrix portrays the raw ratings made by the seven clinicians. From this matrix, the Perceived Causal Clinician Network was constructed using the package "qgraph" version 1.0.5 in R 3.0.1 software (Epskamp et al. 2011). Only those causal relations endorsed by the majority of the clinicians ($\geq$4) were presented in the Perceived Causal Clinician Network. The network was then visually analysed for: strength of node connections (e.g., clustering), and the importance of specific nodes (e.g., centrality), and causal tendency. The Perceived Causal Clinician Network was not used to make any statistical inferences for the Data Network(s).

The centrality measures depict information about individual nodes. This allows for the identification of the most "central" nodes, and thus focal points of a network (Opsahl et al. 2010). We discuss two quantitative measures of centrality: degree and betweenness (Freeman 1979).

The degree in a directed causal network, such as the Perceived Causal Clinician Network, has two components. Out-degree is a measure of departing edges from the node, reflecting the degree to which the symptom directly *causes* other symptoms. In-degree is a measure of incoming edges to the node, reflecting the degree to which a node is the direct *effect* of other nodes. Nodes with the highest degree values are discussed, as they represent the nodes that were thought by the clinicians to cause (or be the effect of) the most other symptoms. For undirected networks, no distinction between in/out-degree is possible, and the relevant measure of centrality is simply the number of connections a node has; this is called the degree of the node.

The betweenness measure is calculated as the proportion of shortest paths between two node pairs that pass through the node of interest (Opsahl et al. 2010). Betweenness is a selective measure in that, often, many nodes have a betweenness equal to zero. A betweenness value of zero indicates that the given node is never found on the shortest pathway between two other nodes. Nodes with a betweenness measure greater than zero may facilitate or inhibit the interaction of one symptom onto another; thus, nodes with high betweenness values are discussed.

Data Network

The nine items used to assess restricted and stereotypic behaviors from the ADI-R and the eight items from the OCD section of the P-DISC-IV were combined into one data set and used to construct the Data Network. Point-bisserial correlations, a special case of the Pearson product-moment correlation for dichotomous data, were computed for each pair of items. From these correlations, the Correlation Data Network was constructed as a weighted network, in which the weights equal the absolute value of the correlation between the corresponding symptoms. The Correlation Data Network was then analysed for strength of node connections (e.g., clustering) and the importance of specific nodes (e.g., centrality).

The Correlation Data Network provides us clues to the possible causal relation between two symptoms, however they do not provide the necessary information from which to infer causal relations between the two symptoms. However, under a (strict) set of statistical assumptions, the causal structure underlying correlational data can be inferred (Borsboom and Cramer 2013). To do so, we used R package "pcalg", version 1.1-5 in R 3.0.1 software (Kalisch et al. 2010), to implement the PC algorithm, a well-developed causal inference method (Pearl 2000; Spirtes et al. 2001). This algorithm tracks the pattern of conditional independencies, and then deduces candidate causal structures that could have generated the observed pattern of conditional independencies. In other words, the algorithm concludes that two symptoms are causally related, if they do not become independent when all other variables (symptoms) in the dataset are held constant (Schmittmann et al. 2011). Conditional independencies were tested against alpha level 0.05. Please note that the

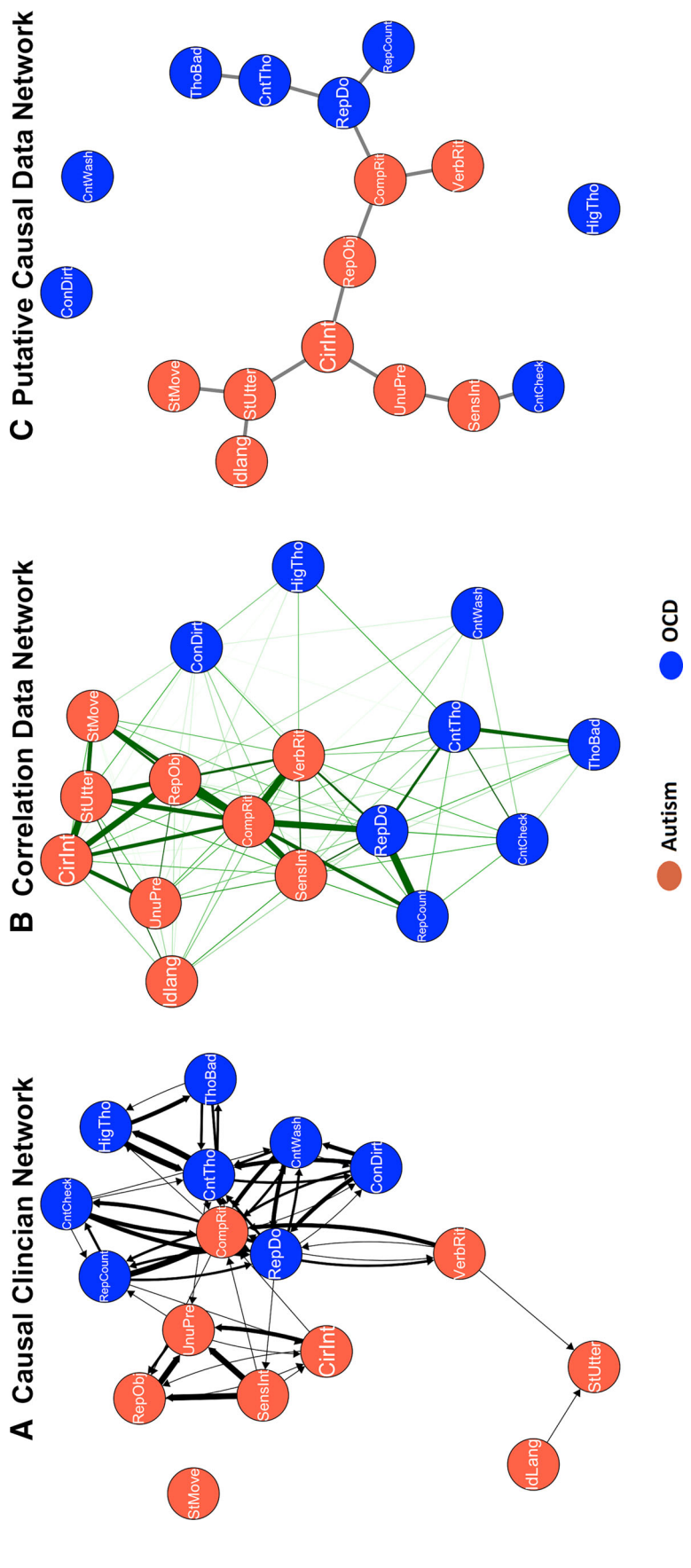

Fig. 1 **a** A network illustrating the inter-relations between repetitive behaviors, characteristic of autism and OCD, according to clinicians. Each *node* represents a symptom of a disorder. An *edge* signifies the presence and direction of a causal relation between two symptoms. The *thickness* of *edges* coincides with increased levels of agreement between clinicians. The *length* of *each edge* is related to the strength of the association between symptoms. **b** A network illustrating repetitive behaviors characteristic of autism and OCD, as they are present in the clinical data set (N = 213). All *edges* are undirected and represent correlations between symptoms. *Edges* were scaled to vary in width and concentration according to a correlation of .3. **c** A network representing the causal skeleton between symptoms of autism and OCD. An *edge* signifies that the relevant symptoms are not independent conditional on (sets of) other symptoms. Since the PC-algorithm yields a dichotomous verdict on the presence of absence of causal links, the network is unweighted and symptom associations are not visually portrayed in the edge widths

Putative Causal Data Network (Fig. 1c) represents an explorative perspective and, therefore, is interpreted as a preliminary view of the causal skeleton of symptoms underlying the Correlation Data Network. Results from both the Correlation and Putative Causal Data Network are independent of the Perceived Causal Clinician Network.

Results

Reliability of the PCR Scale Ratings

The number of causal relations endorsed by the seven clinicians varied from 37 to 140 ($M = 78.14$, $SD = 33.40$). All included symptoms, along with the short labels used in the networks, are presented in Table 1.

Cronbach's alpha was used to assess the reliability of the average ratings from the PCR scale. For the composite rater score, Cronbach's alpha equals .73; this indicates a sufficiently strong signal in the data to warrant interpretation of the resulting network.

Autism Symptoms

The Perceived Causal Clinician Network (Fig. 1a) shows autism nodes as a distinct cluster from OCD nodes. This is due to increased agreement between clinicians that direct causal relations are more common between two autism nodes as compared to an autism node with an OCD node. Nodes *unusual preoccupations* and *compulsions and/or rituals* are focal points of the autism cluster; each node has high out-degree, in-degree, and betweenness values (Table 1).

The Correlation Data Network (Fig. 1b) also portrays two clusters: autism nodes and OCD nodes. This is confirmed, as the shortest path lengths (distances) are significantly shorter within a cluster than between clusters ($t\ (121.6) = -4.3$, $p \leq .001$***). The Putative Causal Data Network (Fig. 1c) also supports autism nodes as a separate component.

We also assessed centrality measures of *unusual preoccupations* and *compulsions and/or rituals*, as these are central nodes in the Perceived Causal Clinician Network. Results partially align between networks. Based on the high degree and betweenness value (Table 1), *compulsions and/or rituals* is a focal node in the network. However, centrality measures do not support *unusual preoccupations* as being a focal node in the network. Instead, *unusual sensory interests* and *verbal rituals* show relatively high association with all other symptoms in the network. Further, the high betweenness values imply that these nodes are integral to the progression of multiple node interactions.

In sum, clinicians believe that repetitive behaviors in autism are more likely to cause or be the effect of other autism symptoms, than they are to cause a symptom that is characteristic of OCD. In particular, they identify unusual preoccupations and compulsive/ritualistic behaviors to generate many of the other repetitive behaviors observed in autism. The empirical data show that a relationship between two autism symptoms is common, and that an interaction between an autism and OCD symptom is less likely. The empirical data also suggests that compulsive/ritualistic behaviors, verbal rituals, and sensory interests are the symptoms to most likely co-occur with other symptoms, and could be key symptoms to the association of autism and OCD symptoms.

OCD Symptoms

The Perceived Causal Clinician Network (Fig. 1a) portrays OCD nodes as a separate cluster from autism nodes; edges are thicker between nodes and are more frequent. Centrality measures (Table 1) show nodes *continual thoughts that do not go away* and *repeatedly do things until it feels good or just right* (further referred to as *repeatedly do things*) as having the highest degree and betweenness values.

The Correlation Data Network (Fig. 1b) does support clustering of the OCD nodes, however this cluster is weak. This is a robust finding also in the Putative Causal Data Network (Fig. 1c). Here, OCD nodes do not cluster together. Three OCD nodes share no causal edges and therefore are unconnected to the network.

Due to indications by the Perceived Causal Clinician Network, specific nodes *continual thoughts that do not go away* and *repeatedly do things* were assessed. Based on the Correlation Data Network, centrality measures support these two symptoms as critical to the OCD network. Further, Fig. 1c renders *continual thoughts that do not go away* and *repeatedly do things* (Fig. 1c) as being causally related.

To summarize, clinicians identified many cause and effect relations to exist between OCD symptoms, but very few to exist between OCD and autism symptoms. More specifically, they view continual thoughts and the urge to repeatedly do things to cause and/or effect the most symptoms in the OCD system. The empirical data also suggests that OCD symptoms co-occur together more often than any OCD and autism symptoms. Of particular interest are the symptoms concern for dirt, continual washing, and thoughts due to a "higher power", because they show no connection to the network in the Putative Causal Data network. This may imply that these symptoms are unlikely to be observed in relation to autism.

Autism Symptoms and OCD Obsessions

In the Perceived Causal Clinician Network (Fig. 1a), obsession nodes only share direct relations with autism

node *compulsions and/or rituals*. Meaning, obsessions are neither the cause nor the effect of any autism nodes.

In the Correlation Data Network (Fig. 1b) obsessions show only moderate to weak association with autism symptoms. Centrality measures (Table 1) indicate c*ontinual thoughts that do not go away* and *concern with things touched due to dirt or bacteria* as the two obsession nodes most involved in the network. Nodes *thoughts of doing something bad around others* and *belief that someone/higher power put reoccurring thoughts in their head* are in part consistent with the Perceived Causal Clinician network; these obsessions are the least associated with other autism nodes, and have considerably lower centrality measures.

However, no causal edge between an obsession node and an autism node were found in the Putative Causal Data Network (Fig. 1c). That is, the direct associations found in the Correlation Data network are not due to a cause and effect relationship. These results correspond to the Perceived Causal Clinician Network.

In sum, clinicians do not view obsessions in OCD to cause or effect any symptoms in autism. According to the empirical data, obsessions are not likely to co-occur with autism symptoms, and this is especially true for thoughts of doing something bad and thoughts due to a "higher power". Our exploration of underlying causal relations between symptoms also suggests that there is no causal relation from an obsession to an autism symptom.

Autism Symptoms and OCD Compulsions

Compulsive symptoms play a significant role in the Perceived Causal Clinician Network (Fig. 1a); *compulsions and/or rituals* and *repeatedly do things* are equally central in the network. These symptoms also have two of the highest in- and out-degree values (Table 1), meaning they are most often a direct cause or effect of another symptom. In addition, their high betweenness values indicate that these two nodes often mediate symptom interactions between autism and OCD.

Node *continual counting/repeating* was the only other compulsive node to share direct relations with autism nodes in the Perceived Causal Clinician Network, specifically with autism nodes, *unusual preoccupations* and c*ircumscribed interests*. However, the betweenness value was zero, indicating little influence in the network. This is further supported by the Putative Causal Data Network, which renders no direct causal relation between *continual counting/repeating* and autism nodes.

The centrality of *compulsions and/or rituals* and *repeatedly do things* is evidenced in the Correlation Data Network (Fig. 1b); both nodes have relatively high degree and betweenness values. Moreover, their edges show increased width. This is also true in the Putative Causal Data Network (Fig. 1c). *Compulsions and/or rituals* and *repeatedly do things* again emerge as the link between the autism node cluster and OCD node cluster, and hence, represent one of only two direct causal relations between an OCD and autism node.

In the Correlation Data Network, autism nodes are linked to the OCD compulsive nodes by moderate to weak associations. In addition, in the Putative Causal Data Network only one compulsive node is unconnected from the network-*continual washing*. Further, two causal edges exist between autism and OCD nodes: (1) *compulsions and/or rituals* and *repeatedly do things*; (2) *unusual sensory interests* and *continual checking*. The latter highlights *unusual sensory interests* as a potential cause of OCD-like compulsions in individuals with autism.

To summarize, clinicians indicate compulsive/ritualistic behaviors (e.g., autism symptom) and the urge to repeatedly do things (e.g., OCD symptom) as the most common cause and effect of autism symptoms. In addition, they view continual counting and repeating as a compulsive behaviour to share a direct influence with autism symptoms, however the empirical data did not support this relationship. Interestingly, compulsive/ritualistic behaviors and the urge to repeatedly do things emerge as the symptoms which links the autism symptom cluster and OCD symptom cluster. Compulsive symptoms do appear to co-occur with autism symptoms, and the causal exploration suggests that sensory interests may actually lead to OCD type compulsion continual checking. Interestingly, this is an autism symptom, which may lead to an OCD symptom.

Discussion

This study has provided the first network-based analyses of the symptomatology connecting autism and OCD. Our results support repetitive behaviors as key components to the link between autism and OCD. However, these disorders consistently emerged as separate symptom clusters, due to stronger and more frequent symptom connections within a disorder. This was indicated by the clinicians and the empirical data, which suggests that unique symptom interactions, and hence processes, distinguish these disorders (Schmittmann et al. 2011).

These findings are highly relevant to the way in which we conceptualize autism in relation to OCD. Often, this link is based on two conceptions: that they represent two distinct, but highly comorbid disorders (Bejerot 2007) or that this is a potential case of symptom overlap (Bartz and Hollander 2006; Ivarsson and Melin 2008). Our results indicate that an alternative conception may be more appropriate. In line with previous research (King et al.

2009), symptoms did emerge as two clusters, which suggest that repetitive behaviors in autism and OCD are not similar behaviors. Obsessions from OCD did not share strong ties with OCD compulsive behaviors, as would be expected in a typical OCD diagnosis, where obsessions cause compulsions. As posited by the network perspective, symptoms have the propensity to directly influence each other (Borsboom and Cramer 2013). It is likely that when an autism-*type* and OCD-*type* symptom co-occur, the result is a different dynamic between symptoms as compared to those interaction that produce an only OCD-*type* symptoms in an individual.

The differences found between autism and OCD can be attributed to the lack of association between autism symptoms and OCD obsessions. Unlike in autism, the OCD diagnosis does admit the importance of causal interactions between symptoms. Hence, the diagnosis of OCD implies that compulsions are behaviors aimed at reducing the distress caused by obsessions (American Psychiatric Association 2013). Part of the difficulty in delineating the association between autism and OCD has hinged on whether such an inter-relation exists among individuals with autism. Based on our results, this does not seem to be the case. Across all networks, obsessions were found to be the least important in the network. Further, the Putative Causal Data Network showed two of the most typical OCD obsessions–*concern with things touched due to dirt or bacteria* and *belief that someone/higher power put reoccurring thoughts in their head*–to lack causal influence in the relation between autism and OCD. Thus, our findings support previous reports that obsessions appear much less frequent and pervasive in individuals with autism as compared to OCD (McDougle et al. 1995), and further question the manifestation of OCD among individuals with autism.

In contrast, our results support ritualistic and compulsive behaviors as an important symptom to the phenomenology of autism. Networks indicated compulsive behaviors *compulsions and/or rituals* and *repeatedly do things* as the key symptoms linking autism and OCD. This indicates that ritualistic and compulsive symptoms have a high propensity to influence other repetitive behaviors, and may in part, determine which symptoms emerge, and to what degree in an individual.

However, this was not true for all compulsive symptoms. Compulsive behaviors typical of OCD, such as *continual washing*, *continual checking*, and *continual counting/repeating* differed in the strength of their association to autism symptoms. This may suggest that for different types of compulsive behaviours there may be a different reason for or effect of the behaviour. Similarly, a recent study suggests that OCD treatments may be more effective if tailored according to the specific type of symptom (Williams et al. 2011).

In contrast, general compulsive behaviors, *compulsions and/or rituals* and *repeatedly do things,* rather than compulsive behaviors typical of OCD, were highly related to autism symptoms. Again, this is in line with a previous study that found that treatments found to be effective in reducing symptomatology in OCD, were not effective for individuals with autism (King et al. 2009). Therefore, while individuals with autism show a collection of ritualistic and compulsive behaviors, it is those compulsive behaviors *not* assessed by the OCD symptoms that exert a significant influence on the symptom profile of individuals.

Lastly, results indicated *unusual sensory interests* as an important symptom in the network. This conclusion is based on high centrality measures computed from the Correlation Data Network as well as the causal relation between autism symptom *unusual sensory interests* and OCD compulsive symptom *continual checking*. Previous research supports this proposition. For instance, a series of case studies suggest that children with OCD were more intolerant of ordinary sensory stimuli, which lead to significant subjective distress, and in turn, time-consuming ritualistic behaviors (Hazen et al. 2008). In addition, sensory processing has been linked to OCD symptoms later in life (Dar et al. 2012). Collectively, these findings implicate *unusual sensory interests,* as a valuable focal point to understand the co-morbid link between autism and OCD, and suggest that there may be divergent pathways to the compulsive behaviors observed in these disorders.

Several study limitations warrant mention. First, repetitive behaviors were assessed using previously collected data from the ADI-R and P-DISC-IV. Both measures are administered to the parent/primary caregiver by a trained interviewer, which helped in the comparison of item responses. However, because this study utilized previously collected data, we were limited to the nine items required for the scoring algorithm of restricted and repetitive behaviors on the ADI-R and the OCD subscale on the P-DISC-IV. The ADI-R has been reported to under sample repetitive behaviors in autism, even when all repetitive behavior items are included (Honey et al. 2012). The P-DISC-IV only includes eight items in the OCD subscale, as compared to other measures, such as the commonly used Yale-Brown Obsessive–Compulsive Scale (Y-BOCS; Goodman et al. 1989), which includes 50 symptoms specific to OCD along with a severity scale. By including more repetitive behaviors, we would gain a more complex understanding of the current networks—there would be an increase in symptom relations, and we mediating symptoms may emerge and account for the symptom relations in the current networks. Future research should view the present networks as a basic visualization that can be built upon.

Second, symptoms differed in their level of specificity. For example, the general symptom *compulsions and/or rituals* versus the more specific symptom *continual checking* may have confounded the interpretation symptom relations. Future research could build upon the present study by including a more expansive and detailed collection of repetitive behaviors and assessing these behaviors at multiple time points. Such efforts could help strengthen our identification of the symptoms that cause repetitive behaviors in autism or OCD. In return, such findings could also be used in clinical settings, as they would pinpoint those symptoms that would be most effective to target in the treatment or each disorder.

The goal of this study was to explore the use of the network approach in understanding psychological disorders, and simultaneously consider the relationship between autism and OCD through their repetitive behaviors. Our results have demonstrated a rich variety of symptom relations, and the significance of these associations seemed to vary as a function of symptom type. The recent movement to affiliate psychological disorders, including autism and OCD, seems to be inspired by the fact that similar symptoms are seen across disorders. However, it is important that scholars do not oversimplify perceived similarities in symptoms as meaning equal in symptom association and function. Network analysis emphasizes the complexity of psychological disorders and this study shows how such complexity can be fruitfully analysed. Eventually, it is anticipated that specific repetitive behaviour patterns are identified, allowing a precise investigation of the mechanisms, processes, and biological underpinnings that may account for the different symptom presentations between individuals. To do so, it is clear that we need new techniques that can accommodate the complex associations between symptoms present in an individual. This study is an initial attempt in this direction.

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