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# NETWORK ANALYSIS IN PSYCHOLOGY

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*El objetivo general de este trabajo es introducir un nuevo enfoque denominado análisis de redes (network analysis) para su aplicación al campo de la psicología. Básicamente, se trata de presentar el modelo de redes, de forma breve, amena, sencilla y, en la medida de lo posible, alejada de tecnicismos y aparataje estadístico. Es un breve bosquejo cuya finalidad es, por un lado, dar los primeros pasos en el análisis de redes, y por otro, mostrar las implicaciones teóricas y clínicas subyacentes a este modelo. En primer lugar, se comentan los orígenes de este enfoque y la forma de comprender los fenómenos psicológicos, concretamente las variables de tinte psicopatológico. Se abordan los conceptos de red, nodo y arista, los tipos de redes y los procedimientos para su estimación. Seguidamente, se explican las medidas de centralidad y se mencionan algunas aplicaciones al campo de la psicología. Posteriormente, se ejemplifica en un caso concreto, estimando y analizando una red de rasgos de personalidad dentro del modelo de los Big Five. Se aporta la sintaxis correspondiente para que el lector pueda practicar. Finalmente, a modo de conclusión, se realiza una breve recapitulación, se comentan algunas notas de reflexión y líneas de investigación futuras.*
***Palabras clave:*** *Análisis de redes, Salud mental, Medición, Psicología, Psicometría, Modelo de redes.*

*The main goal of this work is to introduce a new approach called network analysis for its application in the field of psychology. In this paper we present the network model in a brief, entertaining and simple way and, as far as possible, away from technicalities and the statistical point of view. The aim of this outline is, on the one hand, to take the first steps in network analysis, and on the other, to show the theoretical and clinical implications underlying this model. Firstly, the roots of this approach are discussed as well as its way of understanding psychological phenomena, specifically psychopathological problems. The concepts of network, node and edge, the types of networks and the procedures for their estimation are all addressed. Next, measures of centrality are explained and some applications in the field of psychology are mentioned. Later, this approach is exemplified with a specific case, which estimates and analyzes a network of personality traits within the Big Five model. The syntax of this analysis is provided. Finally, by way of conclusion, a brief recapitulation is provided, and some cautionary reflections and future research lines are discussed.*
***Key words:*** *Network analysis, Mental health, Measurement, Psychology, Psychometric, Network model.*

Psychology, since its inception, has not ceased in its efforts to improve our understanding of human behavior. This continuous impulse has driven the development of different psychological models that, in essence, aim to further our knowledge of behavior and psychological processes (in a broad sense). The new theoretical and psychometric models may allow us to incorporate an alternative prism with which to conceptualize and rethink psychological phenomena. The network model, chaos theory and dynamic systems theory are just some examples that, despite being classic themes in some scientific disciplines, are just being incorporated into the science of human behavior (Nelson, McGorry, Wichers, Wigman, & Hartmann, 2017). The contributions of the network model for the analysis of psycho(patho)logical variables are especially interesting (Borsboom, 2017; Borsboom & Cramer, 2013). This new way of understanding and intervening in behavior has enormous possibilities since it can, among other things, motivate alternative ways of analyzing data, suggest different ways of modeling and analyzing the relationships between variables (e.g., symptoms, signs, psychological processes, personality traits, environmental triggers, substance use, etc.), design new forms of prevention and intervention strategies and/or even improve the search for etiological mechanisms.

Within this context the objective of this work is to provide an introduction to network analysis in psychology. Our aim is to present the network model in a brief, entertaining and simple way and as far from technicalities and complex statistical jargon as possible. The goal is for

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it to serve as an introductory tutorial for the psychology practitioner and to allow us, on the one hand, to take the first steps in network analysis, and on the other, to understand the theoretical and clinical implications underlying this model. The thread of exposition in the present work will be as follows. Firstly, the origins of this approach are discussed as well as its way of understanding psychological phenomena, specifically psychopathological type variables. The concepts of network model, node and edge, the types of networks and the procedures for their estimation are addressed. Next, centrality measures are explained and some applications to the field of psychology are mentioned. Subsequently, this is exemplified in a specific case, estimating and analyzing a network of personality traits within the Big Five model. The corresponding syntax is provided so that the reader can practice it. Finally, by way of conclusion, a brief recapitulation is made, some notes of general reflection as well as possible limitations are discussed and future lines of investigation are presented.

## THE ANALYSIS OF NETWORKS IN PSYCHOLOGY

Network analysis represents a recent theoretical approach in psychology, although it is not new in the scientific field. It has been applied extensively in other areas under graph theory, for example, in the study of social relationships (Borgatti, Mehra, Brass, & Labianca, 2009; Newman, 2010).

Professor Denny Borsboom of the University of Amsterdam and his group of collaborators have promoted a different vision with which to conceptualize, specifically, psychopathological problems (Borsboom & Cramer, 2013; Schmittmann et al., 2013). It is expanding to other areas of psychology that go beyond the study of mental disorders, such as intelligence or voting attitudes (Maas, Kan, Marsman, & Stevenson, 2017). Basically, the network model is emerging as a response to the medical model, predominant in the field of psychiatry and some areas of psychology, which has been promulgated by the main nosological systems. For example, from the Diagnostic and Statistical Manual of Mental Disorders (DSM) (American Psychiatric Association, 2013), it is considered that the symptoms and signs that patients refer to have their origin in a latent cause called "mental disorder" or "mental illness". The symptoms are mere passive consequences of a common latent cause. This interpretation is known as the 'common latent disorder' or 'common cause model' (Borsboom & Cramer, 2013). It is assumed, for example, that phenotypic manifestations such as hallucinations, delusions or negative symptoms are due to an underlying disorder that is causing them, in this case called schizophrenia (see Figure 1). This medical approach to the understanding of abnormal behavior seems to stem from a false premise: a common latent cause. Obviously this vision is not without limitations. For example, unlike other fields of medicine, in psychopathology it is difficult to identify a common cause as a condition that exists independently of its symptoms and that explains their emergence and covariance (McNally, 2016). In addition, this approach leads to tautological reasoning (a person has hallucinations because they suffer from a psychotic episode; they are diagnosed with schizophrenia psychosis because they report having hallucinations) and also to reification. In response to these possible limitations, nosological systems have also been criticized by other international associations with new ways of conceptualizing and classifying mental problems even being proposed (e.g., *Research Domain Criteria* –RDoC- of the National Institute of Mental Health) (Insel et al., 2010).

As Fonseca-Pedrero (2017) points out, the 'common latent cause' model is undoubtedly one of the most useful ways of explaining mental disorders; however, other interpretations, whether complementary or otherwise, that allow a full understanding of psychopathological disorders as well as other psychological phenomena (e.g., personality traits) are possible, as well as desirable. We wish to exemplify this point with a case. Take, for example, a person with sleep problems, which disturb their mood and their reasoning processes, making them suspicious. In turn, over time these behaviors lead to a state of general malaise and paranoid ideation that negatively impact their ability to concentrate and their academic/work performance. All this ends up unleashing a set of auditory hallucinatory experiences that alter their social functioning, generating disability and the need for treatment. The visual representation of this hypothetical case is shown in Figure 2. If this model is taken into account, an underlying mental disorder, named schizophrenia, would not be the common cause of the covariance between the signs and symptoms. The symptoms are grouped because they influence each other mutually, and not because there is a common latent cause that is explaining their emergence and covariation. The symptoms do not reflect "the cause" but are constitutive of it (McNally, 2016). Therefore, one might think that psychopathological symptoms and signs are not the emerging manifestations of an underlying mental disorder but rather they are networks of symptoms, dynamic complex systems or dynamic constellations of symptoms (and signs) that are causally interrelated (Borsboom & Cramer, 2013; Fried, van Borkulo, Cramer, et al., 2016). Based on the network model, psychopathological disorders are conceived as a complex dynamic system (Cramer et al., 2016). It is a system because it analyzes direct relationships between symptoms. It is complex because the result cannot be predicted by considering only one element of the system. It is dynamic because it evolves over time.

For a more detailed analysis of network analysis the reader can consult the previous excellent works both in English (Borsboom, 2017; Borsboom & Cramer, 2013; Epskamp, Maris, Waldorp, & Borsboom, in press; McNally, 2016; Schmittmann et al., 2013) and Spanish (Fonseca-Pedrero, 2017), tutorials (Borsboom & Cramer, 2013; Costantini et al., 2017; Costantini et al., 2015), websites (http://psychosystems.org/; http://psych-networks.com/; http://eiko-fried.com/), apps for analyzing and representing the networks (https://jolandakos.shinyapps.io/NetworkApp/ o http://ncase.me/loopy/v1.1/) or sintaxis in the *R* environment (http://sachaepskamp.com/files/Cookbook.html). Readers who wish to take their first steps using *R* can consult the excellent manuals and introductory articles (Elosua, 2009; Field, Miles, & Field, 2012; R Core Team, 2016; Ruiz-Ruano & Puga, 2016).

## BASIC CONCEPTS IN THE ANALYSIS OF PSYCHOLOGICAL NETWORKS

### *Network, nodes and edges*

A network is an abstract model that contains nodes and edges. The nodes represent the objects or variables of the study, while the edges represent the connections between the nodes, that is, the "link" that connects them (see Figure 3). Nodes can be all sorts of variables such as, for example, psychopathological symptoms, personality traits, or environmental triggers (e.g., traumatic experiences, cannabis use) (Isvoranu et al., 2017; Klippel et al., 2017). They could also be some other type of variable from levels of analysis not observable to the human eye (e.g., genetic, brain, psychophysiological, neurocognitive) (Santos Jr, Fried, Asafu-Adjei, & Ruiz, 2017). The existing graphical representation between nodes and edges is known as a graph. Such representations can be executed in *R* (R Core Team, 2016) and with specific packages such as *Qgraph* (Epskamp, Cramer, Waldorp, Schmittmann, & Borsboom, 2012).

### *Classification of networks*

There are different types of networks, depending on whether the edges are weighted or not and/or directed or not. Four types result from their combination, namely: unweighted not directed, unweighted directed, weighted not directed, and weighted directed. Figure 4 shows a visual representation of this taxonomy.

FIGURE 1
EXAMPLE OF REPRESENTATION OF MENTAL DISORDER BASED ON THE MEDICAL MODEL OF 'COMMON LATENT CAUSE' (REFLECTIVE MODEL)

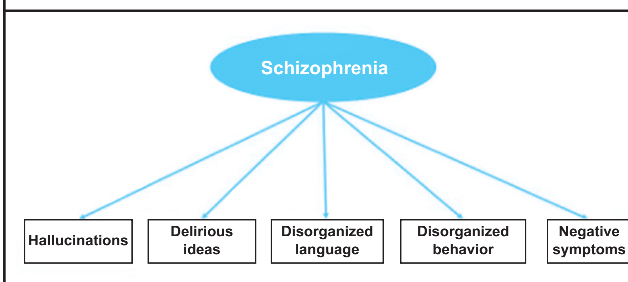
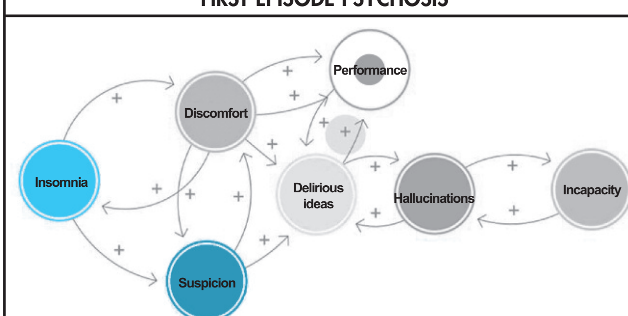



FIGURE 2
POSSIBLE THEORETICAL MODEL OF RELATIONS BETWEEN SYMPTOMS PROPOSED FOR A PATIENT DIAGNOSED WITH A FIRST EPISODE PSYCHOSIS




Note: This inter-relation between symptoms has to be seen dynamically (not statically). Since it is a model, it should be seen as a simplification of reality that has been presented here for expository and didactic purposes. Made with http://ncase.me/loopy/v1.1/.

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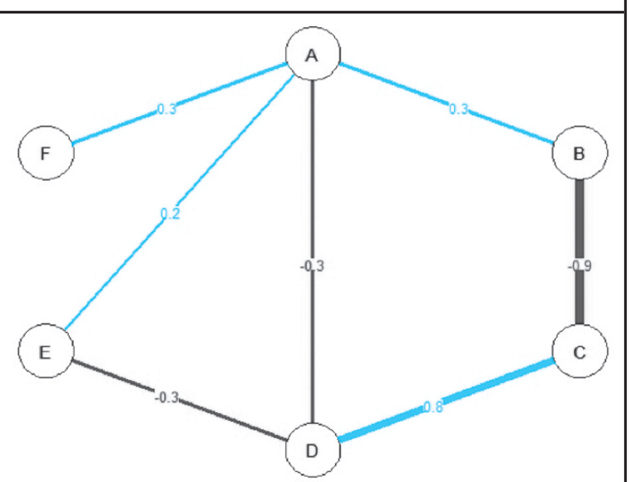
First, the edges of the networks can be weighted or unweighted. In unweighted networks the nodes are connected without any force or weight, whereas in the weighted networks there is a value, a coefficient, which is indicative of the magnitude of this connection. This value is represented by the thickness of the edge and oscillates between - / + 1. The closer to +1 or -1 the value is, the greater the thickness of the edge and the greater the strength of the association between nodes. It follows that the association between nodes can be positive or negative. A negative association, negative sign of the coefficient, is usually represented with the color red and a positive one, with a positive sign of coefficient, is represented with the color green. A value of 0 indicates the absence of an edge connecting the nodes.

Second, the edges of the networks can be non-directed or directed. Undirected networks consist of edges or simple lines connecting pairs of nodes, where there is an association of a certain magnitude, but the direction of this relationship is not indicated (e.g., if node *X* causes the activation of node *Y*, or vice versa). Graphically the colored lines (red and green) that connect the nodes would not have arrows at their end point. For their part, directed networks allow the direction of the prediction between nodes to go both ways. Directed networks consist of edges with arrowheads at one end of the edge, pointing in the direction of the prediction, and perhaps causal relationships.

**FIGURE 3**
**EXAMPLE OF ESTIMATED NETWORK**

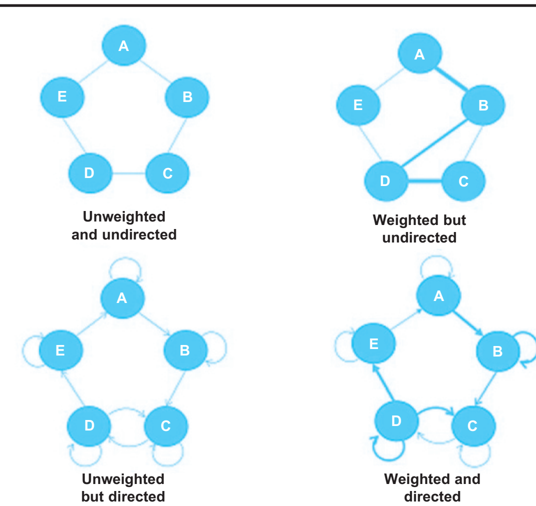



Note. The circles represent nodes (variables). The edges represent the relationship between the nodes. For example, node *A* could represent suicidal ideation, node *B* bullying, etc. The greater the value of the edge coefficient, the thicker the line and therefore the stronger association between nodes. The green color of the edge indicates a positive relationship between nodes (variables). The red color of the edge indicates a negative relationship between nodes (variables).

### *Network estimation*

Psychological networks need to be estimated. This estimation is based on a matrix of correlations that can basically be of three types: a) simple; b) partial; and c) partially regularized. The simple correlations, or association network, are the graphical representation derived from the Pearson correlation matrix. The partial correlations, or concentration network, allow us to see the correlation between node *A* and node *B* controlling the effect of the rest of the nodes of the network, that is, controlling the spurious correlations that can emerge due to the multiple comparisons. The estimation of the network is carried out by means of an algorithm called *Fruchterman-Reingold*. Regularized partial correlations implement a regularization procedure, which essentially requires fewer parameters to be estimated so it allows us to extract a stable and easy to interpret network. In this case, the network can be estimated with the Least Absolute Shrinkage and Selection Operator (LASSO) or with a variation called Graphical-LASSO (G-LASSO) (Epskamp, Borsboom, & Fried, 2017). The choice of estimation method is not a trivial matter and should not be left to chance because it can have a great impact both on the resulting structure of the

**FIGURE 4**
**TYPES OF NETWORKS**



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estimated network and on the conclusions drawn from this structure (Epskamp, Kruis, & Marsman, 2017).

### *Analyzing the structure of the network: centrality measures*

Based on the estimated network, different inferences can be made that help us to understand its structure as well as examine the relative importance of the nodes within it. To analyze the structure of the network, there are measures of: a) distance and shortest path length; b) centrality; and c) connectivity and clustering. Only the measures of centrality will be presented here, so the reader who wishes to learn more about the other measures of network inference can consult the previous works (Costantini et al., 2015).

Centrality measures ask which is the most important node in the network. They allow us to analyze the relative importance of the node within the network depending on the pattern of connections. In an estimated network not all nodes are equally important. A node is central if it has many connections. A node is peripheral, i.e., it is on the outside of the network, if it has few connections. In order to know if the node is central (important and influential) in the network, the following must be taken into account: a) degree and strength; b) closeness; and c) betweenness.

Strength centrality refers to the magnitude of the association with the other nodes, i.e., it is close to other nodes. A node with a high centrality in this parameter is a node that influences many other nodes. Closeness centrality is defined as the inverse of the sum of the distance from one node to all other nodes in the network. A node with a high closeness centrality index is a node that can predict other nodes well. Betweenness is defined as the number of times a node is between two other nodes. Betweenness is the number of shortest paths between any two nodes (the shortest route from node A to node B) that passes a specific node.

Statistical programs allow us to extract these centrality indexes (in *Z* scores), referring to strength, closeness and/or betweenness, as well as generating graphs and tables based on them (see Figures 5 and 6 below).

## SOME APPLICATIONS IN THE FIELD OF PSYCHOLOGY

It has not been until relatively recently that the psychological literature has focused on a network approach to model psychological phenomena. In this short history, excellent scientific contributions have been made, a true reflection of the interest it has aroused among professionals and researchers in psychology and related sciences. The themes of study under the network model are current topics under great expansion. Serving as a sample are works that have analyzed depressive symptomatology (Bringmann, Lemmens, Huibers, Borsboom, & Tuerlinckx, 2015; Cramer et al., 2016; Fried, van Borkulo, Epskamp, et al., 2016), psychosis and its relationship with traumatic experiences or environmental impacts (Isvoranu, Borsboom, van Os, & Guloksuz, 2016; Isvoranu et al., 2017), negative psychotic symptoms (Levine & Leucht, 2016), attenuated psychotic symptoms (Fonseca-Pedrero, 2018), substance abuse (Rhemtulla et al., 2016), quality of life (Kossakowski et al., 2016), post-traumatic stress symptoms (McNally et al., 2014), comorbidity (Cramer, Waldorp, van der Maas, & Borsboom, 2010), relationship between symptoms and disorders from taxonomic systems (Boschloo et al., 2015; Tio, Epskamp, Noordhof, & Borsboom, 2016), emotional and behavioral problems (Boschloo, Schoevers, van Borkulo, Borsboom, & Oldehinkel, 2016; Fonseca-Pedrero, 2017), and intelligence (Maas, Kan, Marsman, & Stevenson, 2017), to name but a few.

Recently Borsboom (2017) has proposed a theoretical model of mental disorders from this perspective. In his theory he posits five theoretical principles in relation to the structure and dynamics of symptom networks, specifically: complexity, symptom-component correspondence, direct causal connections, mental disorders follow network structure, and hysteresis. First, complexity refers to the interaction that is established between the different components of the network. Second, correspondence refers to the relationship between the components of the network and the symptoms of psychological problems. Third, the structure is generated by a pattern of direct connections between the symptoms. Fourth, the psychopathological network has a nontrivial topology, that is, some symptoms are more strongly connected than others (e.g., a particular symptom within a mental disorder is more connected to the symptoms of that specific disorder than to the symptoms of other clinical syndromes). Fifth, hysteresis refers to the phenomenon by which a certain event external to the network (e.g., traumatic experiences) can affect it and the subsequent absence of such event or external event does not necessarily deactivate the network. In other words, the symptoms continue to activate each other even when the external trigger event has disappeared. Finally, from this model, the notion of mental health would correspond to a stable state of a weakly connected network, whereas mental disorders would correspond to stable states of networks of strongly connected symptoms. For example, under this approach psychopathological syndromes (see for example psychotic disorders) are conceived as dynamic causal networks of mental states with increasing levels of psychopathological severity, an aspect totally consistent with current staging models (Fonseca-Pedrero, 2018; McGorry & van Os, 2013; Nelson et al., 2017; Wigman et al., 2013).

Network theory has clear implications for our way of understanding the psychological diagnosis and treatment. For example, structural analysis of the psychological network and centrality measures have clear clinical implications. It is possible to judge which symptoms are most important in the network, to use the most central symptoms to diagnose and plan the treatment or focus the treatment on a symptom or the network of symptoms that have the most connections. It is also possible to identify "bridge" symptoms, that is, a symptom that serves as a link between two sets of networks and whose approach and intervention may enable the of controlling the (hypo)activation of other subnetworks. For Borsboom (2017) the diagnosis involves identifying networks of symptoms, while the treatment involves changing or manipulating the psychopathological network in three ways, namely: a) interventions on symptoms (modifying the status of one or more symptoms); b) interventions in the external field (eliminating the triggering cause or causes); and c) network interventions (modifying the connections between the nodes of the network, i.e., symptom-symptom). For example, in the case of a patient with a psychotic spectrum disorder in which an antipsychotic treatment is implemented, a family intervention can be considered to modify communication patterns or eliminate substance use, and/or work with cognitive behavioral techniques that allow us to cope with the delusions of persecution in order to reduce the associated hallucinatory experiences. As the reader can see, all of these issues are highly relevant to clinical practice.

## AN EXAMPLE OF NETWORK ANALYSIS IN PERSONALITY

In this section we present, briefly and by way of example, a network analysis of personality, specifically to analyze the big five factors of personality (Extraversion – E; Conscientiousness –C; Openness –O; Agreeableness – A; Neuroticism, –N) evaluated using 25 items (see appendix). Each of these dimensions is valued using five items. A sample of 2,800 participants was used ($M$ = 28.8 years, $SD$ = 11.1 years), which is available in the "psych" package (Revelle, 2015) of the *R* environment (R Core Team, 2016). The network was estimated using *Qgraph* (Epskamp et al., 2012). The estimated network is weighted and not directed. The G-LASSO algorithm was used. The reader can find the corresponding syntax in the appendix.

The results of both the estimated psychological network and the centrality indexes are presented in Figures 5 and 6. It was previously noted that a node is central if it has many connections and its centrality basically depends on the strength, closeness and betweenness. Figure 6 shows the standardized values referring to these three parameters. The indices are all on the same scale of measurement, and they are standardized ($z$ scores), which allows the comparison among them. As can be seen, the items that had the highest coefficients of centrality in strength were C4 ("Doing things by halves") and C2 ("Continuing until everything is perfect"). In closeness, items O4 ("Taking time to reflect on things"), E5 ("Taking control") and E4 ("Making friends easily") had the highest coefficients of centrality. And in betweenness, items N4 ("Often feeling sad"), E4 ("Making friends easily") and C2.

The items in the Conscientiousness dimension seem to have the strongest connections. In this case, the strength of centrality reflects the probability with which the activation of one of these nodes (items/characteristics) will be followed by the activation of other nodes in the network. The items of the Extraversion dimension and item 4 of Openness presented a high closeness centrality, indicating that they are nodes that can predict other nodes (items/traits) of the network well. Items N4, E4 and C2 presented a high centrality of betweenness. In other words, they are nodes (items/traits) that are often located between (in the middle of) other nodes and passing through them are the shortest paths among other nodes of the network.

It is worth noting that for a correct interpretation of the network the reader should not only focus their assessment on a visual inspection. A problem to be avoided in

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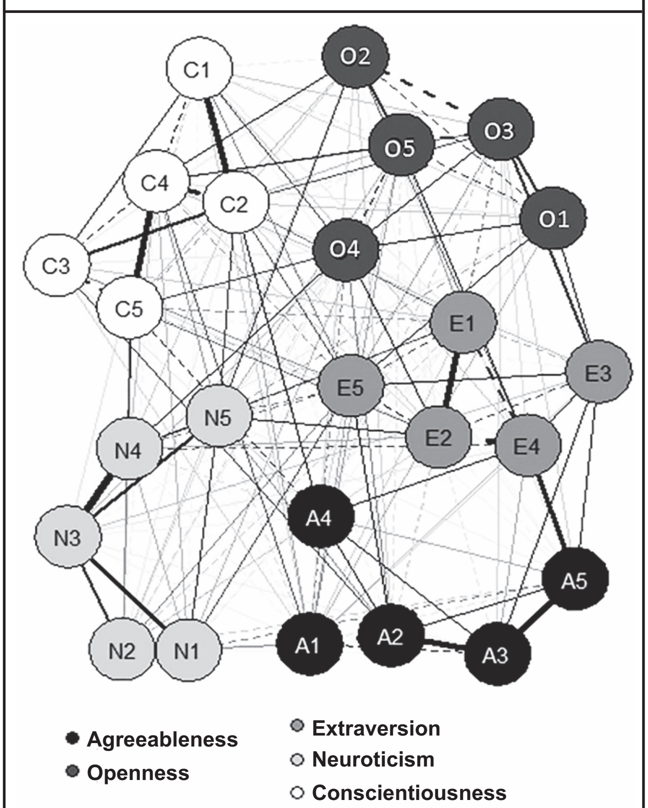
psychological networks is precisely over-interpretation at the time of their visualization. This aspect refers especially to the design and placement of nodes in the graph, for example, when the nodes of the network are grouped in a cluster. However, the reader needs to know that the location of the node within a network is only one of many equally 'correct' ways of placing the nodes in the network, i.e., in the same sample the location of the nodes in the network could be different in a new estimate. Therefore, we must be cautious when making a visual interpretation of the nodes and their position in the network. Although it is not the subject of this tutorial, for a better interpretation of the psychological network one could analyze the communalities (Golino & Epskamp, 2017) and/or predictability (Haslbeck & Fried, 2017).

From these results we can better understand the structural relationship established between the big five personality traits, as a complex system of affective, cognitive, and behavioral characteristics.

**FIGURE 5**
**ESTIMATED NETWORK FOR PERSONALITY TRAITS FROM THE BIG FIVE MODEL**




Note. The numbers of the nodes represent the items of the questionnaire (see Annex). Extraversion -E; Conscientiousness –C; Openness -O; Agreeableness -A; Neuroticism, -N

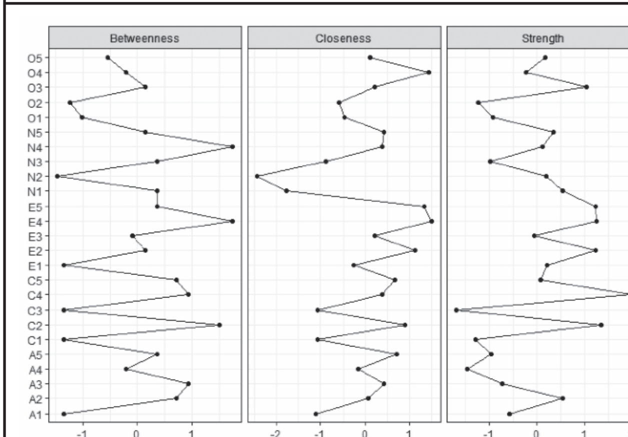
## RECAPITULATION

The purpose of this article was to provide an introduction to the analysis of psychological networks. In essence the aim was to present this fertile approach to the psychology professional in a completely didactic way.

Currently, the network model is presented in society as a promising approach in the way of conceptualizing psycho(patho)logy (Fried & Cramer, 2017). In fact, some authors believe that network analysis can transform the field of psychopathology (McNally, 2016) to a certain extent. Based on the network model an underlying latent variable would not be the cause of the covariance of the symptoms, nor would the symptoms be interchangeable indicators of an underlying disorder. Consequently, the symptoms do not reflect underlying mental disorders, they are constitutive of them. For this reason, network analysis can have a relevant role in the understanding of, for example, psychopathological phenomena, avoiding the limitations of the medical model based on a common latent cause. It is understood that network analysis can provide clues about the psychological mechanisms that underlie the development and maintenance of mental health problems.

It is essential to incorporate different viewpoints and perspectives that help us to rethink human behavior (in a broad sense). There is no doubt that the understanding

**FIGURE 6**
**CENTRALITY MEASURES FOR THE ITEMS OF THE PERSONALITY QUESTIONNAIRE**




Note. For a correct interpretation, the values of the *X* axis are standardized (Z scores). The numbers correspond to the items in the questionnaire (see Annex). Extraversion –E; Conscientiousness –C; Openness, –O; Agreeableness –A; Neuroticism, –N.

and study of human behavior is a complex task, in which an infinite number of variables operate from multiple levels of analysis (biological, psychological, and social). In any case, whether or not the network model helps change the current epistemological and methodological approach to psychology, specifically psychopathology, at least this approach is presented as a new approach from which to observe, measure, analyze, understand and intervene in psycho(patho)logical phenomena (Fonseca-Pedrero, 2017). In essence, it aims to respond to certain problems that some areas of current psychology suffer from, such as overcoming the notion of the latent variable and the supposed underlying cause. Obviously, network analysis should not be seen as incompatible with other theoretical and methodological approaches, but rather as a complementary approach. Its correct use and its usefulness depend on the objective of study and the particular interests of the clinician or researcher as well as on other aspects such as the appropriate use and quality of the measurement instruments used (Fonseca-Pedrero & Muñiz, 2016, 2017; Hernández, Ponsoda, Muñiz, Prieto, & Elosua, 2016).

Research in network analysis is currently in its infancy, so it is necessary to continue working on the construction of a solid and refutable scientific model and to incorporate new scientific evidence (Borsboom, 2017). Obviously, this model is not exempt from limitations and some authors have made certain precautionary reflections (Guloksuz, Pries, & van Os, 2017; Wichers, Wigman, Bringmann, & de Jonge, 2017). First, studies under this perspective have a clear time cost, especially those that perform longitudinal follow-ups on the participants. Second, psychometric network models have not yet been consolidated and are computationally complicated, even for experts in the field. Third, we must distinguish between the scientific studies that allow an analysis under this perspective and those that do not. In other words, not all studies have to be seen from the prism of networks. Fourth, the network method with its impressive and elegant technology may be detrimental to qualitative narrative analyses and prototypical rather than polythetic classifications. Fifth, psychological networks involve (and at the same time have a tendency towards) homogenizing the symptoms, when the same symptoms could be qualitatively different, an aspect that requires a phenomenological analysis of their qualitative differences (Parnas, 2015; Pérez Álvarez, 2012; Pérez-Álvarez & García Montes, 2018; Sass, 1992). Sixth, one should not engage in a kind of methodologicizing. In other words, the method must be at the service of the psycho(patho)logical issues and problems and not vice versa. Seventh, consideration should be given to the need to incorporate measurement error in the estimation of the network.

Many interesting lines of research will open up in the coming years. First, it would be interesting to move towards models of multilevel networks that allow us to integrate studies that gather information from multiple levels of analysis, within a translational and interdisciplinary strategy. Second, it would be useful to start analyzing behavior from a perspective that is dynamic (longitudinal), personalized (individual), and staging (severity levels) (Fusar-Poli, McGorry, & Kane, 2017; Nelson et al., 2017; Van Os et al., 2013) including the possibility of designing strategies for the diagnosis, intervention or even functional analysis of behavior. For example, individualized interventions could be designed based on the estimated network structure and connectivity of the signs and symptoms. Fourth, it would be interesting to make simpler and "more user friendly" statistical programs and packages that could be used by the psychology practitioner to enable, among other things, the establishment of relationships between symptoms at the scale on which the clinician works.

The network model represents an advance in the approach, understanding and measurement of psychological phenomena. Naturally, future studies will determine the true usefulness and depth of the network model in psychology. Be that as it may, the road ahead is exciting, to say the least.

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**CONFLICT OF INTERESTS**

There is no conflict of interest in this article.

## REFERENCES

American Psychiatric Association. (2013). *Diagnostic and Statistical Manual of Mental Disorders (5th ed.).* Washington, DC: American Psychiatric Association.

Borgatti, S. P., Mehra, A., Brass, D. J., & Labianca, G. (2009). Network Analysis in the Social Sciences. *Science*, *323*, 892–896.

Borsboom, D. (2017). A network theory of mental disorders. *World Psychiatry*, *16*, 5–13.

Borsboom, D., & Cramer, A. O. (2013). Network analysis: an integrative approach to the structure of psychopathology. *Annual Review of Clinical Psychology*, *9*, 91–121.

Boschloo, L., Schoevers, R. A., van Borkulo, C. D., Borsboom, D., & Oldehinkel, A. J. (2016). The network structure of psychopathology in a community sample of preadolescents. *Journal of Abnormal Psychology*, *125*(4), 599–606.

Boschloo, L., van Borkulo, C. D., Rhemtulla, M., Keyes, K. M., Borsboom, D., & Schoevers, R. A. (2015). The network structure of symptoms of the diagnostic and statistical manual of mental disorders. *PLoS One*, *10*(9), e0137621.

Bringmann, L. F., Lemmens, L. H. J. M., Huibers, M. J. H., Borsboom, D., & Tuerlinckx, F. (2015). Revealing the dynamic network structure of the Beck Depression Inventory-II. *Psychological Medicine*, *45*, *747–57*.

Costantini, G., Epskamp, S., Borsboom, D., Perugini, M., Mõttus, R., Waldorp, L. J., & Cramer, A. O. J. (2015). State of the aRt personality research: A tutorial on network analysis of personality data in R. *Journal of Research in Personality*, *54*, 13–29.

Costantini, G., Richetin, J., Preti, E., Casini, E., Epskamp, S., & Perugini, M. (2017). Stability and variability of personality networks. A tutorial on recent developments in network psychometrics. *Personality and Individual Differences*. https://doi.org/10.1016/j.paid.2017.06.011.

Cramer, A. O. J., van Borkulo, C. D., Giltay, E. J., van der Maas, H. L. J., Kendler, K. S., Scheffer, M., & Borsboom, D. (2016). Major depression as a complex dynamic system. *Plos One*, *11*(12), e0167490.

Cramer, A. O. J., Waldorp, L. J., van der Maas, H. L. J., & Borsboom, D. (2010). Comorbidity: a network perspective. *The Behavioral and Brain Sciences*, *33*(2–3), 137–193.

Elosua, P. (2009). ¿Existe vida más allá del SPSS? Descubre *R* [Is there life beyond SPSS? Discover *R*]. *Psicothema*, *21*(4), 652–655.

Epskamp, S., Borsboom, D., & Fried, E. I. (2017). Estimating psychological networks and their accuracy: a tutorial paper. *Behavior Research Methods*, 1–34.

Epskamp, S., Cramer, A. O. J., Waldorp, L. J., Schmittmann, V. D., & Borsboom, D. (2012). qgraph: Network visualizations of relationships in psychometric data. *Journal of Statistical Software*, *48*(4), 1–18.

Epskamp, S., Kruis, J., & Marsman, M. (2017). Estimating psychopathological networks: Be careful what you wish for. *PLoS ONE*, *12*(6).

Epskamp, S., Maris, G., Waldorp, L. J., & Borsboom, D. (in press). Network psychometrics. In P. Irwing, D. Hughes, & T. Booth (Eds.), *Handbook of Psychometrics*. New York, NY: Wiley.

Field, A., Miles, J., & Field, Z. (2012). *Discovering Statistics Using R*. London: SAGE.

Fonseca-Pedrero, E. (2017). Análisis de redes: ¿una nueva forma de comprender la psicopatología? [Network analysis: A new way of understanding psychopathology?] *Revista de Psiquiatria y Salud Mental*, *10*, 206-215.

Fonseca-Pedrero, E.(Coordinador) (2018). *Evaluación de los trastornos del espectro psicótico [Assessment of psychotic spectrum disorders]*. Madrid: Pirámide.

Fonseca-Pedrero, E., & Muñiz, J. (2016). Advances in psychological assessment. *Papeles del Psicólogo*, *37*, 1-2.

Fonseca-Pedrero, E., & Muñiz, J. (2017). Quinta evaluación de tests editados en españa: mirando hacia atrás, construyendo el futuro [Fifth review of tests published in Spain: Looking back, building the future]. *Papeles del Psicólogo*, *38*, 161–168.

Fried, E., & Cramer, A. (2017). Moving forward: challenges and directions for psychopathological network theory and methodology. *Perspectives on Psychological Science*, doi: 10.1177/1745691617705892.

Fried, E. I., van Borkulo, C. D., Cramer, A. O. J., Boschloo, L., Schoevers, R. A., & Borsboom, D. (2016). Mental disorders as networks of problems: a review of recent insights. *Social Psychiatry and Psychiatric Epidemiology*, *58*(12), 7250–7257.

Fried, E. I., van Borkulo, C. D., Epskamp, S., Schoevers, R. A., Tuerlinckx, F., & Borsboom, D. (2016). Measuring depression over time . . . Or not? Lack of unidimensionality and longitudinal measurement

invariance in four common rating scales of depression. *Psychological Assessment*, 28, 1354-1367.
Fusar-Poli, P., McGorry, P.D., & Kane, J.M. (2017). Improving outcomes of first-episode psychosis: an overview. *World Psychiatry, 16*, 251-265.
Golino, H. F., & Epskamp, S. (2017). Exploratory graph analysis: A new approach for estimating the number of dimensions in psychological research. *PLoS ONE, 12*(6).
Guloksuz, S., Pries, L.-K., & van Os, J. (2017). Application of network methods for understanding mental disorders: pitfalls and promise. *Psychological Medicine*, *5*, 1–10.
Haslbeck, J. M. B., & Fried, E. I. (2017). How predictable are symptoms in psychopathological networks? a reanalysis of 17 published datasets. *Psychological Medicine*, 19, 1-10.
Hernández, A., Ponsoda, V., Muñiz, J., Prieto, G., & Elosua, P. (2016). Revisión del modelo para evaluar la calidad de los tests utilizados en España [Assessing the quality of tests in Spain: Revision of the Spanish test review model]. *Papeles del Psicólogo, 37*, 161–168.
Insel, T., Cuthbert, B., Garvey, M., Heinssen, R., Pine, D. S., Quinn, K., … Wang, P. (2010). Research domain criteria (RDoC): toward a new classification framework for research on mental disorders. *The American Journal of Psychiatry*, *167*(7), 748–751.
Isvoranu, A.-M., Borsboom, D., van Os, J., & Guloksuz, S. (2016). A network approach to environmental impact in psychotic disorder: brief theoretical framework. *Schizophrenia Bulletin*, *42*(4), 870–873.
Isvoranu, A. M., van Borkulo, C. D., Boyette, L. L., Wigman, J. T. W., Vinkers, C. H., & Borsboom, D. (2017). A Network approach to psychosis: pathways between childhood trauma and psychotic symptoms. *Schizophrenia Bulletin*, *43*, 187-196.
Klippel, A., Viechtbauer, W., Reininghaus, U., Wigman, J. T., van Borkulo, C., MERGE, … Wichers, M. (2017). The cascade of stress: a network approach to explore differential dynamics in populations varying in risk for psychosis. *Schizophrenia Bulletin*, doi: 10.1093/schbul/sbx037.
Kossakowski, J. J., Epskamp, S., Kieffer, J. M., van Borkulo, C. D., Rhemtulla, M., & Borsboom, D. (2016). The application of a network approach to health-related quality of life: introducing a new method for assessing HRQoL in healthy adults and cancer patients. *Quality of Life Research, 25*, 781–792.
Levine, S. Z., & Leucht, S. (2016). Identifying a system of predominant negative symptoms: Network analysis of three randomized clinical trials. *Schizophrenia Research*, *178*, 17-22
Maas, H. Van Der, Kan, K., Marsman, M., & Stevenson, C. E. (2017). Network models for cognitive development and intelligence. *Journal of Intelligence*, *5*, 16; doi: 10.3390/jintelligence5020016.
McGorry, P., & van Os, J. (2013). Redeeming diagnosis in psychiatry: timing versus specificity. *Lancet*, *381*, 343–345.
McNally, R. J. (2016). Can network analysis transform psychopathology? *Behaviour Research and Therapy*, *86*, 95–104.
McNally, R. J., Robinaugh, D. J., Wu, G. W. Y., Wang, L., Deserno, M. K., Borsboom, D., … Borsboom, D. (2014). Mental disorders as causal systems : a network approach to posttraumatic stress disorder. *Clinical Psychological Science*, *3*(6), 1–14.
Nelson, B., McGorry, P. D., Wichers, M., Wigman, J. T. W., & Hartmann, J. A. (2017). Moving from static to dynamic models of the onset of mental disorder. *JAMA Psychiatry*, *74*, 528-534.
Newman, M. E. J. (2010). *Networks: An Introduction*. Oxford, United Kingdom: Oxford University Press.
Parnas, J. (2015). Differential diagnosis and current polythetic classification. *World Psychiatry*, *14*, 284–287.
Pérez Álvarez, M. (2012). *Las raíces de la psicopatología moderna: La melancolía y la esquizofrenia [The roots of modern psychopathology: Melancholy and schizophrenia].* Madrid: Ediciones Pirámide.
Pérez Álvarez, M. & García Montes, J. (2018). Evaluación fenomenológica
más allá de los síntomas [Phenomenological assessment
beyond the symptoms], In E. Fonseca-Pedrero (Coordinador). *Evaluación de los trastornos del espectro psicótico [Assessment of psychotic spectrum disorders].* Madrid: Pirámide.
R Core Team (2016). *R: A Language and Environment for Statistical Computing*. Vienna, Austria.
Revelle, W. (2015). Package "psych" - Procedures for Psychological, Psychometric and Personality Research. *R Package*, 1–358. Retrieved from http://personality-project.org/r/psych-manual.pdf
Rhemtulla, M., Fried, E. I., Aggen, S. H., Tuerlinckx, F.,

Kendler, K. S., & Borsboom, D. (2016). Network analysis of substance abuse and dependence symptoms. *Drug and Alcohol Dependence*, *161*, 230–237.

Ruiz-Ruano, A. M., & Puga, J. L. (2016). R como entorno para el análisis estadístico en evaluación psicológica [R as the environment for data analysis in psychological assessment]. *Papeles del Psicólogo, 37*, *74–79*.

Santos Jr, H., Fried, E. I., Asafu-Adjei, J., & Ruiz, R. J. (2017). Network structure of perinatal depressive symptoms in latinas: relationship to stress and reproductive biomarkers. *Research in Nursing & Health, 40*, 218-228.

Sass, L.A. (1992). *Madness and modernism. Insanity in the light of modern art, literature, and thought*. Harvard University Press.

Schmittmann, V. D., Cramer, A. O. J., Waldorp, L. J., Epskamp, S., Kievit, R. A., & Borsboom, D. (2013). Deconstructing the construct: A network perspective on psychological phenomena. *New Ideas in Psychology*, *31*(1), 43–53.

Tio, P., Epskamp, S., Noordhof, A., & Borsboom, D. (2016). Mapping the manuals of madness: Comparing the ICD-10 and DSM-IV-TR using a network approach. *International Journal of Methods in Psychiatric Research*, *25*, 267-276.

van Os, J., Delespaul, P., Wigman, J., Myin-Germeys, I., Wichers, M., (2013). Beyond DSM and ICD: introducing "precision diagnosis" for psychiatry using momentary assessment technology. *World Psychiatry*, *12*, 113–117.

Wichers, M., Wigman, J. T. W., Bringmann, L. F., & de Jonge, P. (2017). Mental disorders as networks: some cautionary reflections on a promising approach. *Social Psychiatry and Psychiatric Epidemiology*, *52*, 143–145.

Wigman, J. T. W., Collip, D., Wichers, M., Delespaul, P., Derom, C., Thiery, E., … van Os, J. (2013). Altered transfer of momentary mental states (atoms) as the basic unit of psychosis liability in interaction with environment and emotions. *PLoS ONE*, *8*(2).

## Appendix

**Figure 2**

http://ncase.me/loopy/v1.1/?data=[[[1,547,236,1,%22Malestar%22,4],[2,315,338,1,%22Insomnio%22,5],[3,535,487,1,%22Suspicacia%22,0],[4,874,357,1,%22Alucinaciones%22,1],[5,698,358,1,%22Ideas%2520delirantes%22,2],[6,1107,351,1,%22Discapacidad%22,3],[7,777,173,0.33,%22Rendimiento%2520%22,1]],[[2,1,94,1,0],[1,2,89,1,0],[2,3,-55,1,0],[1,5,-4,1,0],[3,5,-25,1,0],[3,1,-59,1,0],[5,4,56,1,0],[4,5,48,1,0],[4,6,54,1,0],[6,4,48,1,0],[1,3,-49,1,0],[1,7,46,1,0],[1,7,-27,1,0],[7,5,-49,1,0],[5,7,-22,1,0]],[[1236,423,%22a%22]],7%5D

**Content of the 25 items used**
(available at: https://www.personality-project.org/r/html/bfi.html)

**Agreeableness**
A1. Am indifferent to the feelings of others.
A2. Inquire about others' well-being.
A3. Know how to comfort others.
A4. Love children.
A5. Make people feel at ease.
**Conscientiousness**
C1. Am exacting in my work.
C2. Continue until everything is perfect.
C3. Do things according to a plan.
C4. Do things in a half-way manner.
C5. Waste my time.
**Extraversion**
E1. Don't talk a lot.
E2. Find it difficult to approach others.
E3. Know how to captivate people.
E4. Make friends easily.
E5. Take charge.
**Neuroticism**
N1. Get angry easily.
N2. Get irritated easily.
N3. Have frequent mood swings.
N4. Often feel blue.
N5. Panic easily.
**Openness**
O1. Am full of ideas.
O2. Avoid difficult reading material.
O3. Carry the conversation to a higher level.
O4. Spend time reflecting on things.
O5. Will not probe deeply into a subject.

Article in press

## Appendix (Continuation)

**Syntaxis in R.**
Install R: https://cran.r-project.org/mirrors.html
For consultation: http://sachaepskamp.com/files/Cookbook.html

```
install.packages("qgraph") # install qgraph package

mat2 <- matrix(c(
 0, 0.3, 0, -0.3, 0.2, 0.3,
 0.3, 0, -0.9, 0, 0, 0,
 0, -0.9, 0, 0.8, 0, 0,
 -0.3, 0, 0.8, 0, -0.3, 0,
 0.2, 0, 0, -0.3, 0, 0,
 0.3, 0, 0, 0, 0, 0), ncol = 6, nrow = 6,  byrow = TRUE)
qgraph(mat2, edge.labels = TRUE,esize = 10, labels = LETTERS[1:6], fade = FALSE) # Figure 1.

library ("psych") # install the psych package
data (bfi) # load the database called "bfi"
view (bfi) # view the database "bfi"
summary (bfi) # computer minimum, maximum, range, media, etc. of the database "bfi"
dim (bfi) # number of variables and cases of the database "bfi"
names (bfi) #name of the variables of the database "bfi"
describe (bfi) # descriptive statistics of the database "bfi"

bfiSub <- bfi [, 1: 25] # selection the first 25 items of the database "bfi"

corMat <- cor_auto (bfiSub) # compute the correlation between the variables of the database "bfi", 25 items, ordinal measurement scale

Groups <-c (rep ("Kindness", 5), rep ("Responsibility", 5), rep ("Extraversion", 5), rep ("Neuroticism", 5), rep ("Aperture", 5)) # generate groups of items that correspond to the five dimensions, each dimension contains 5 items

Graph_lasso <- qgraph (corMat, graph = "glasso", layout = "spring", tuning = 0.25, sampleSize = nrow (bfiSub), groups = Groups, palette = "colorblind") # estimate network with 25 items and 5 dimensions with the GLASSO method, Figure 5

centralityPlot (Graph_lasso) # estimate the centrality indices, Figure 6
```