

# Critiques of network analysis of multivariate data in psychological science



A recent Primer on the network analysis of multivariate data in psychological science (Borsboom, D. et al. Network analysis of multivariate data in psychological science. *Nat. Rev. Methods Primers* 1, 58 (2021)) provided an overview of psychometric network analysis, including graphical models, estimation methods for those models and descriptive tools<sup>1</sup>. These techniques are used for obtaining and examining the statistical associations among psychological variables as a network. However, the Primer omitted or glossed over core critiques of these models and methods, making them appear artificially robust and widely accepted. We highlight four categories of critique: selecting network models when better-suited multivariate methods already exist, adopting study designs that are mismatched to research questions, estimating networks using methods that yield unreliable estimates and interpreting network metrics that are invalid when applied to networks of statistical associations. We point readers to selected critiques that were available when the original Primer was written, and also provide a complete annotated bibliography<sup>2</sup> of critiques of psychometric network analysis.

## Model selection

The goal of psychometric network analysis is to understand the relationships among measured psychological variables, including symptoms, beliefs or traits. However, many multivariate methods already exist for this purpose. For example, latent variable models such as factor analysis and structural equation methods already allow researchers to examine the relationships among a set of measured variables, and offer robust ways to evaluate model fit. A series of debates in both clinical and personality psychology have challenged whether psychometric network analysis is the most appropriate method for research questions focused on understanding patterns of variable associations. Some have observed that network models may be identical in many cases to latent variable models; however, because of their structure and

number of parameters, network models may overfit and be lacking in parsimony<sup>3</sup>. Similarly, others note that network models do not provide value beyond a graphical depiction of the correlations or partial correlations among the variables<sup>4</sup>. Following these observations, we recommend that researchers conduct psychometric network analysis only when it is better matched to their research questions than other existing multivariate analytic methods.

## Study design

The majority of psychometric network analyses are conducted on between-person and cross-sectional data. This design ensures that psychometric networks cannot “offer clues to causal dynamics” among symptoms or beliefs in individuals. Despite the Primer’s claims that “network models ... explicitly represent pairwise interactions between components in a system”, the authors only explicitly represent pairwise statistical associations, and therefore do not “form a natural bridge from data analysis to theory formation”<sup>1</sup>. First, it is not possible to use between-person statistical associations among symptoms or beliefs to draw conclusions about how those symptoms or beliefs are related for a given individual, even a member of the sample. To do so is an ecological fallacy, and “the visually attractive network graphs enhance this tendency” to commit such fallacies<sup>5</sup>. Second, it is not possible to use cross-sectional data to make causal inferences because correlations among variables – even regularized partial correlations estimated using sophisticated techniques – do not indicate causality. Indeed, comparisons to inferences drawn from longitudinal data reveal that cross-sectional psychometric networks “do not reflect how symptoms trigger each other over time”<sup>6</sup>. Therefore, we recommend that researchers refrain from making inferences about causality or within-person processes when using between-person cross-sectional data.

## Estimation reliability

The strength of connections between symptoms or beliefs in psychometric networks are operationalized using measures of statistical

association estimated from empirical data on a sample of subjects. Identifying which of these connections are robust and reliable is critical because they define the structure of the network. However, the estimation of psychometric networks from multivariate data typical in psychological science often yields unreliable estimates. For example, the fitting of multiple types of conditional independence models, when applied to multiple epidemiological samples, yielded unreliable estimates of individual connections and nodes’ centralities<sup>7</sup>. Indeed, compared with Monte Carlo fixed-marginal models common in network science, psychometric network models yielded “results ... indistinguishable from what would be expected by chance”<sup>8</sup>. More broadly, although psychometric networks may appear similar when relying on global summary statistics, the detailed characteristics of the networks interpreted in the literature typically vary substantially with even small differences in study samples and methods<sup>9</sup>. Because the robustness of estimated psychometric networks remains questionable, we recommend that researchers exercise caution in drawing inferences for clinical research or practice before results have been rigorously replicated.

## Interpretation of measures

The symptoms or beliefs in psychometric networks are often characterized by their centrality in the network. However, most network centrality metrics were developed for networks that are both bounded and composed of social actors, and lose their interpretability when applied to unbounded networks of variables. The Primer briefly noted that “if important nodes are missing, this can affect the structure of the network” and that “there are no clear guidelines” for interpreting centrality in psychometric networks<sup>1</sup>, but this glosses over the severity of the problem. First, it is often impossible for psychometric networks to include all important nodes because the universe of relevant symptoms or beliefs is unknown and uncountably large. Exacerbating this issue, the Primer recommends that

researchers decide which nodes to include in the network after data collection, rather than a priori to inform data collection. Simulations have revealed that these practices render centrality measures invalid in psychometric networks<sup>10</sup>. Second, most centrality metrics are designed to measure the flow of information or influence among distinct and exchangeable nodes. By contrast, psychometric networks measure statistical associations among correlated variables representing symptoms and beliefs that vary in severity or intensity. Therefore, hypotheses that link node centrality to symptom or belief importance are ill defined<sup>11</sup>. Because psychometric networks typically have unknown levels of node missingness, and in the absence of an explicit conceptual rationale for their applicability, we recommend that researchers consider more appropriate alternatives to centrality metrics when analysing psychometric networks.

## Conclusion

Network methods have a long history and many potential applications in psychology. However, these critiques highlight that there are important but under-recognized limitations in psychometric network analyses of variables measuring symptoms, beliefs or traits.

There is a reply to this letter by Borsboom, D. et al. *Nat. Rev. Methods Primers* <https://doi.org/10.1038/s43586-022-00178-8> (2022).

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## Author contributions

Z.P.N. conceptualized the paper. Z.P.N., M.K.F. and J.W.N. drafted the proposal and first draft. All authors drafted and reviewed the final paper.

## Competing interests

The authors declare no competing interests.

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