Unfolding the Complex Dynamic Interplay Between Attentional Processes and Anxiety: A Commentary on Ghassemzadeh, Rothbart, and Posner

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Abstract: Theories about the involvement of attention in feelings of fear and anxiety have been debated in philosophical circles since long before the foundation of experimental psychology and cognitive neuroscience. In this issue, Ghassemzadeh, Rothbart, and Posner (2019) provide a much-needed historical and conceptual review of the relations between attention and anxiety disorders. Throughout their paper, they argue that insights from the study of brain networks of attention offer a particularly viable prospect for best clarifying the complex relations between attentional processes and anxiety. We fully share this view. Moreover, we believe that the computational and conceptual tools of network analysis (also known as graph theory) can enable researchers to move even closer to elucidating the complex dynamic interplay between those phenomena. In this commentary, we explain why and how to use network analysis for this purpose.

Key Words: graph theory, network analysis, anxiety, anxiety disorders, attention, alerting network, orienting network, executive network

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A vital concern for any living creature is the need to be able to pay attention to crucial information amid all the irrelevant distractors that constantly bombard us. In particular, the ability to rapidly orient attention toward threats in the environment is one of the most basic survival needs (LeDoux, 2014). Even so, studies have shown that systematic perturbations in attentional abilities, especially regarding attentional selectivity in relation to threat-related stimuli, may figure prominently in the maintenance, and perhaps the etiology, of anxiety and related disorders (eg, Bar-Haim et al, 2007; Cisler and Koster, 2009; Eysenck and Derakshan, 2011; Heeren et al, 2013, 2015c, 2015d). That should not come as a surprise: theories about the involvement of attention in feelings of fear and anxiety have interested philosophical circles since long before the foundation of experimental psychology and cognitive neuroscience (for reviews, see Fox, 2008; Hilgard, 1980).

Taking stock of this issue, Ghassemzadeh et al (2019) have provided a timely and much-needed narrative review of the relations between attention and anxiety disorders. They also promote the notion that insights from the study of brain networks of attention can be highly beneficial to clarify the complex relations between attention and anxiety. According to the brain-networks perspective of attention, attention systems can be conceptualized as a multifaceted construct including three neuroanatomically (but overlapping brain regions) and functionally distinct attentional networks (eg, Fan et al, 2005; Petersen and Posner, 2012; Posner and Rothbart, 2007). These are the *alerting network* (ie, maintenance of alertness), the *orienting network* (ie, selective engagement and disengagement with certain stimuli rather than others), and the *executive network of attention* (ie, top-down control of attention exemplified by maintenance of attention on certain stimuli and resisting distraction by other stimuli).

We agree with Ghassemzadeh et al (2019) that insights from the study of brain networks of attention offer a viable prospect for anxiety research (see our previous works for illustrations: Heeren et al, 2015a, 2015b, 2015c; Heeren and McNally, 2016a). We share the view that a better understanding of the complex interplay between distinct attentional processes and anxiety symptoms (or any other psychological processes presumably involved in anxiety disorders such as fear, avoidance, rumination) is the critical next step in this field of research. Accordingly, we believe that the computational and conceptual tools of network analysis (Borsboom and Cramer, 2013; McNally, 2016) can enable us to move closer to elucidating the complex dynamics between those phenomena. In this commentary, we explain why and how to use network analysis for this purpose.

During the last decades, network science has transformed disciplines such as ecology, physics, and sociology (Barabási, 2012). With the recent advances of Borsboom and others at both the theoretical (Borsboom, 2017)

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and computational levels (Costantini et al, 2015; Epskamp et al, 2012), we are entering a period when this "network takeover" (Barabási, 2012) is opening new vistas for understanding psychological constructs (Borsboom, 2017; Heeren and McNally, 2016b; Jones et al, 2017; McNally, 2016).

According to this approach, psychological constructs are conceptualized as emergent phenomena that arise from causal interactions among their constitutive elements (Borsboom, 2017; McNally, 2016). For instance, the symptoms of a given anxiety disorder do not cohere because they are caused by a common underlying cause (whether construed categorically or dimensionally), but rather because of causal interactions among the symptoms themselves (Borsboom, 2017; Borsboom and Cramer, 2013; McNally, 2016). In other words, the relation of the constitutive elements of the disorder to the disorder per se is not one of cause and effect; it is mereological—that is, part(s) to whole (Borsboom, 2008).

At the empirical level, estimations of network models of psychopathology were initiated in clinical psychology by Borsboom and his colleagues (eg, Borsboom et al, 2011; Cramer et al, 2010) and have been increasingly applied to psychopathology (for reviews, see Fried et al, 2017; McNally, 2016). Cutting-edge computational methods enable one to visualize disorders as complex network systems comprising symptoms (node) and the associations (edges) connecting them. So far, most network models have elucidated associations between psychiatric symptoms (eg, Fried et al, 2015; Heeren and McNally, 2018; McNally et al, 2017; Robinaugh et al, 2014; Rodebaugh et al, 2018).

Network analysis, however, has not been confined to clinical psychology. Researchers have started to apply network analysis to study personality, neurocognitive mechanisms, and behavioral processes (eg, Bernstein et al, 2017, 2019; Cramer et al, 2012; Heeren et al, 2018a; Heeren and McNally, 2016a; Hoorelbeke et al, 2016; Jones et al, 2017; Jonker et al, 2019; Kraft et al, 2019; Pe et al, 2015).

Network analysis also has clinical promise. Its use enables identification of the most influential or central elements of a network system, based on the amount (and direction) of influence that flows from one node to other ones in the network (Borgatti, 2005; Opsahl et al, 2010). Highly influential nodes are hypothesized to drive the instigation, maintenance, and slowing of the network system (Hofmann and Curtiss, 2018; Robinaugh et al, 2016). Hence, turning off highly central nodes may foster a cascade of downstream benefits, deactivating other nodes (via both direct and indirect connections) and reducing the overall network connectivity (McNally, 2016; Valente 2012; but see Rodebaugh et al, 2018).

Given how Ghassemzadeh et al (2019) postulate a highly determining role of the three attentional networks in the onset and maintenance of anxiety disorders, we suggest that viewing those attentional processes and anxiety symptoms as interacting nodes embedded within a network system can provide a radically new lens on the way those processes interact. Justifications for that suggestion are provided in the following paragraphs.

First, despite evidence already supporting strong correlations between the impairments in the attentional networks and anxiety symptoms (eg, Heeren et al, 2015b; Moriya and Tanno, 2009; Pacheco-Unguetti et al, 2011), quantifying the importance of each node in the network system (Boccaletti et al, 2006; Opsahl et al, 2010) could help to identify particularly potent attentional processes that may foster broader vulnerability for anxiety disorders. For instance, studying social anxiety disorders, Heeren and McNally (2016a) illustrated the way that network analysis can precisely test how attention processes and anxiety unfold. In their study, they estimated the functional relations between the three distinct attentional networks, attentional bias for threat, and fear and avoidance of social situations in a sample of patients with social anxiety disorder. Using centrality analysis, the authors found that the orienting network of attention was the most influential node in determining the predictive dynamics of the entire network structure, especially via the impact of this node on nodes denoting fear and avoidance, but not vice versa. However, because this study only included people with social anxiety disorder, uncertainty still abounds regarding how attentional network and anxiety symptoms unfold in people with other anxiety disorders.

Second, a computational network perspective could help researchers to empirically test whether the distinct features of a system cohere as a large unitary network of interacting elements or constitute distinct communities (or subnetworks) of nodes serving different functions. Indeed, a critical property of complex network systems is community structure. A community is a group of nodes that are highly interconnected, but only sparsely connected to other groups of nodes (Fortunato, 2010). Most real-world networks, such as those involving routers or brain regions, contain communities (eg, Sporns and Betzel, 2016). Detecting communities has practical implications. For instance, it can be more relevant to identify central nodes within communities in order to understand network function than to identify central nodes within an entire network (eg, Beveridge and Shan, 2016; Fan et al, 2012).

Hence, one may wonder whether attentional processes and anxiety symptoms cohere as a single large network system or constitute distinct communities of nodes (ie, subnetworks). Similarly, one may wonder whether the network of people with and without anxiety disorders has the same community structure. And if so, are specific nodes denoting attentional processes particularly influential in triggering anxiety symptoms because they function as "bridges"—that is, processes that are connected or are shared by communities (eg, Bernstein et al, 2019; Heeren et al, 2018b), a pivotal phase in the identification of targets ripe for prevention and intervention? Moreover, from a network perspective, re-activation of those bridges after treatment may be more likely to propagate activation through both nodes, denoting attentional processes and anxiety symptoms. Thus, a network perspective may help to test whether attentional processes do act as harbingers of relapse, constituting prodromal signals deserving careful audit during follow-up sessions (for a discussion, see Cramer et al, 2010).

Third, the network approach to mental disorders (eg, Borsboom, 2017) implies that the overall network connectivity should be higher in people with anxiety disorders than those without anxiety disorders—a prediction confirmed in several symptom-based network studies (eg, Heeren and McNally, 2018; van Borkulo et al, 2015). Indeed, networks with strong between-symptom connections should be more pathogenic than similar networks with weaker connections because, in the former, the activation of any node can easily trigger other nodes and spread to the entire network, activating and self-reinforcing the whole network system (Barrat et al, 2004; Valente, 2012). In this way, one may predict that the overall network connectivity of nodes denoting distinct attentional processes differs between people with anxiety disorders and those without anxiety disorders. Because prior studies indicated that global network connectivity can predict the prognosis of mental disorders (eg, Schweren et al, 2017; van Borkulo et al, 2015), such knowledge may set the scene for radically novel indicators of anxiety prognosis based, for instance, on the overall strength of the associations between the three attentional processes.

Finally, a computational network perspective could also help researchers to empirically explore the temporal dynamics of the interactions between attentional processes and anxiety symptoms. Notably, the trajectory of such a complex dynamic network may differ between anxious and nonanxious individuals. To best capture the dynamic interplay among those distinct features (ie, how they may trigger each other over time), one would need to apply computational methods that characterize the within- and between-person temporal dynamics of intensive intra-individual time series data denoting these systems and their related features (eg, Aalbers et al, 2018; Epskamp et al, 2018). Moreover, techniques from the study of sudden transitions in ecosystems (eg, Hirota et al, 2011) may also help identify when a network system is on the brink of tipping into a disordered state (eg, disorder, relapse) or returning to an ordered one (ie, mentally healthy one).

In conclusion, we propose that network analysis can enable researchers to move closer to elucidating the complex dynamics between attentional processes and anxiety symptoms. This radically new lens could ultimately have clinical implications, such as identifying specific targets (eg, attentional processes triggering anxiety symptoms over time) for meaningful intervention via idiographic network analysis (Epskamp et al, 2018; Fisher et al, 2017). Because attentional alterations have been reported across distinct mental and neurologic disorders (eg, Araneda et al, 2015; Coussement et al, 2019; Heeren et al, 2014; Lannoy et al, 2017, 2019; Maurage et al, 2014, 2017; Togo et al, 2013), future research could also examine the complex dynamic interplay between attentional processes and symptomology across different clinical populations.

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