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Utilizing Network Analysis to Uncover Intolerance of Uncertainty's Structure and Its Anxiety and Depression Link

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Recently, there has been a growing interest in intolerance of uncertainty (IU) as a transdiagnostic risk factor for various mental disorders. However, no consensus has been reached on the components that comprise IU. Considering that while the relationship between IU and internalizing symptoms such as anxiety and depression has been well-established, a dearth of studies elucidates how each IU component is specifically related to anxiety and depression. Given its close relationship to internalizing symptoms, understanding the distinct correlations between each IU facet and internalizing symptoms becomes pivotal for effective interventions. Therefore, this study conducted a network analysis to delineate IU structure and how each component is related to state/trait anxiety and depression. Using the Intolerance of Uncertainty Scale (IUS), the most central item, structure, and relationship within the scale were identified. The relationship between IU and internalizing symptoms was also examined and the clinical implications of each result are discussed.

Keywords: intolerance of uncertainty, network analysis, state anxiety, trait anxiety, depression

Introduction

As there has been a growing interest in transdiagnostic approaches in the treatment and diagnosis of mental disorders (Lynch et al., 2021; Paulus et al., 2015), the examination of a specific transdiagnostic factor has become a crucial part of the psychopathology literature. One widely studied dispositional risk factor for mental disorders is intolerance of uncertainty (IU). IU is defined as "a disposition characteristic that results from a set of negative beliefs about uncertainty and its implications and involves the tendency to react negatively on an emotional, cognitive, and behavioral level to uncertain situations and events" (Buhr & Dugas, 2009).

Previous research has extensively explored the measurement and structural aspects of IU. One frequently employed instrument for measuring IU is the 12-item Intolerance of Uncertainty Scale (IUS-12), which has been repetitively validated through many studies (Bottesi et al., 2020; Carleton et al., 2007; Helsen et al., 2013; Khawaja & Yu, 2010; Ren et al., 2021). IUS-12 is a short version of the Intolerance of Uncertainty Scale (IUS; Freeston et al., 1994) comprised of 27 items. Most studies have proposed a two-factor structure of IUS-12, consisting of "prospective anxiety", which denotes fear and anxiety regarding future events, and "inhibitory anxiety", which describes the inhibition of actions or experiences due to uncertainty (Birrel et al., 2011; Carleton et al., 2007; Helsen et al., 2013).

Recently, Bottesi and colleagues (2020) suggested a three-factor

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The study procedures were carried out in accordance with the Declaration of Helsinki. The research was approved by the Institutional Review Board of Yonsei University. The ethics committee waived the requirement of written informed consent for participation, and thus informed consent through online survey was acquired.
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structure, namely, 'behavioral reactions to uncertainty,' 'emotional reactions to uncertainty,' and 'negative beliefs about uncertainty.' In addition, another study demonstrated negative associations between some IUS items and anxiety symptoms, suggesting the presence of heterogeneity in IUS items. This line of literature shows that there is still no consensus regarding the structure of IU. Considering this possible heterogeneity in IU, it is plausible that different IU components may have distinct associations with depression and anxiety, respectively.

IU has been extensively investigated secondary to its relationship with anxiety disorders. In the model of generalized disorder (GAD), IU was suggested as the core factor which maintains the course of GAD (Dugas et al., 1997), and this has also been empirically supported by subsequent studies (Buhr & Dugas, 2006; Lee et al., 2010). IU is also known to be related to other anxiety disorders such as panic disorder (Carleton et al., 2014), agoraphobia (McEvoy & Mahoney, 2012), and social anxiety disorder (Boelen & Reijntjes, 2009). Although IU was once hypothesized to have a more specific relationship to anxiety disorders, increasing literature has also indicated that individuals with depression also demonstrate a high level of IU than healthy controls (Carleton et al., 2012; Dar et al., 2017; Jensen et al., 2016; Mahoney & McEvoy, 2012). Several meta-analyses also demonstrated moderate positive correlations between IU and anxiety, depression, and related disorders (Gentes & Ruscio, 2011; McEvoy et al., 2019).

Although both anxiety and depression are highly associated with IU, and the comorbidity rate of the two disorders demonstrates their close relationship (Lamers et al., 2011; Zhiguo & Yiru, 2014), they can be differentiated by certain constructs as well. According to the tripartite model, while anxiety and depression hold the shared component of negative affect in common, they can be distinguished by positive affect and physiological hyperarousal (Anderson & Hope, 2008; Clark & Watson, 1991). Individuals with depression tend to exhibit lower levels of positive affect than those with anxiety which can be expressed as fatigue, tiredness, and inactivity. In contrast, individuals with anxiety tend to be physically more aroused. Furthermore, a previous study distinguished the properties of IU related to depression and anxiety. In a multiple regression study, depression was associated with inhibitory IU after controlling for trait anxiety but not with prospective IU, which may show its unique relationship with IU (Jensen et al., 2016). More specifically, some individuals may engage in behaviors to reduce uncertainty (Krohne et al., 2002), while others may prefer to live with pessimistic certainty (Dupuy & Ladouceur, 2008; Yook et al., 2010). These results are in line with the tripartite model in that individuals with depression experience a lack of energy which usually leads to behavioral withdrawal. Considering these distinctions between anxiety and depression, it is crucial to control for the presence of one another and thoroughly examine each condition individually. Thus, we incorporated anxiety, depression, and IU in the same model to gain a better understanding of the unique relationship between each condition.

When exploring the association between anxiety symptoms and IU, it is essential to acknowledge that state and trait anxiety are distinct constructs. State anxiety represents a temporary emotional state characterized by physiological arousal and subjective feelings, while trait anxiety refers to an individual's inherent disposition to respond (Endler & Kocovski, 2001; Spielberger, 1966). Previous research has indicated that levels of state and trait anxiety exhibit distinct patterns among individuals with depression (Addolorato et al., 2008). Given the differential associations of state and trait anxiety with depression, it becomes imperative to examine how these two constructs are specifically linked to the IU constructs.

We employed network analysis to shed light on the structure of IU and the relationship among each item of IUS, the total score of depression, state anxiety, and trait anxiety. Network analysis refers to a statistical method that examines and visualizes the relationship between variables. A network consists of nodes (variables such as individual symptoms of a disorder or a construct) and edges (statistical relationships such as partial correlation). Network analysis has multiple advantages over traditional methods such as correlation analysis and parallel analysis. For one, network analysis offers an intuitive representation of the intricate relationship between multiple variables (Epskamp et al., 2012; Golino et al., 2020; Hevey et al., 2018), unlike traditional methods such as correlation analysis, which represents results in tables and show the relationship between every two variables. Secondly, in addition to this important feature, it offers even more information on the relationship between variables, thus, in the field of psychopatholo-

gy literature, there has been a growing interest in the utility of network analysis to understand disorders and their potential predictors as integrated networks (Borsboom & Cramer, 2013; Hevey, 2018). This involves examining symptom structure (Lazarov et al., 2020; Martel et al., 2016; McNally et al., 2022) as well as identifying particular symptoms contributing to the comorbidity of the two disorders (Afzali et al., 2017; Levinson et al., 2017).

Since IU is known to consist of various dimensions (Birrel et al., 2011; Carleton et al., 2007; Helsen et al., 2013), it is more appropriate to focus on the relationship between individual items of IUS and emotional disorders rather than solely considering the effect of total IUS score. Additionally, analyzing the structure of IUS through network analysis allows for a different understanding of the quantitatively similar IUS scores based on their patterns. Moreover, as network analysis enables the visualization of partial correlation among the variables, the relationship between IU and depression, as well as IU and anxiety, after controlling for each other's effects, can be examined.

Although there are some studies using network analysis to examine the relationship between IU and emotional disorders, most have focused on the effect of IU by simply summing the total score of the IUS. In particular, there has yet to be research targeting the Korean population to gain knowledge on the structure of IUS through network analysis. Furthermore, to the best of our knowledge, no study has investigated the network consisting of IU, depression, and state and trait anxiety in one network. Thus, this study examined the following research questions:

1. To what extent do IUS items demonstrate correlations with each other while controlling for the effects of anxiety and depression symptoms?
2. How can the structure of IU be shown using network analysis, and does this methodology yield insights into the heterogeneity within IU?
3. How are depression symptoms, state anxiety, trait anxiety, and IUS items interrelated, considering the interplay between these variables and controlling for one another?

Methods

Participants

An online survey was conducted from October 25th to December 14th, 2021. Participants were recruited in two ways. First, some participants were recruited via the SONA system. SONA System is an online platform where researchers can collect data from participants and manage the research process (www.sona-systems.com). The department of psychology in our affiliated institution utilizes the SONA system to manage the research pool and give course credit to students who took at least one psychology course. Thus, we used this system to make sure we recruit the students of our affiliated institution. Second, we also recruited students of the same university through a website only its students can access. Once participants enrolled in this study via Sona System or the website, an external link to the online survey was sent to their e-mail. The online survey was constructed using a survey platform, Qualtrics, through which informed consent was also obtained. Upon completion of the survey, those who enrolled in this study via the Sona system got two-course credits, while those who enrolled in the study through the website were granted a coffee voucher equivalent to $8. This study was approved by the authors' affiliated university Institutional Review Board (7001988-202306-HR-1244-10).

A total of 557 data were collected. However, only 272 data were included in the analysis after excluding participants who dropped out ($n = 214$), used duplicate ID ($n = 32$), failed at least one of two attention check items ($n = 24$), or did not meet the eligibility criteria ($n = 14$). Of the 272 subjects, 75.7% were female, and 24.3% were male. Subjects' age ranged from 18 to 24 ($M = 22.1$, $SD = 13.49$).

Measures

The short form of the Intolerance of Uncertainty Scale

Freeston and colleagues (1994) developed the original 27 items of the Intolerance of Uncertainty Scale (IUS) in French, which was subsequently translated into English (Buhr & Dugas, 2002). Then, the short form of the IUS was developed by Carleton et al. (2007) to resolve the cross-loading problem and establish a stable factor structure for inconsistent findings in the scale's factor structure. The short form of IUS consists of 12 items, and a higher score indicates higher intolerance of uncertainty. Participants responded to each item on a five-point Likert scale, where one corresponds to "not at all characteristic of me", and five corresponds to "entirely characteristic of me". The Cronbach's α for IUS-12 was .91 in Carleton (2007). The whole scale of IUS was translated into Korean by

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Choi (1997), which was later revised in short form by Kim (2010). The Korean version of IUS-12 (KIUS)'s Cronbach's α was .84. In this study, the Korean version of the IUS (KIUS) was used, and Cronbach's α for the scale was .94.

The Center for Epidemiologic Studies Depression Scale

The Center for Epidemiologic Studies Depression Scale (CES-D) was developed by Radloff (1977) as a screening tool for depression by measuring symptoms and events experienced over the preceding week. It consists of 20 items, and participants responded on a four-point Likert scale with zero corresponding to "Rarely or none of the time" and three corresponding to "All the time." The Korean version of this scale (K-CES-D) validated by Chon et al. (2001), was utilized in this study. The Cronbach's α for the scale ranged from .85 to .90 during the development of the scale (Radloff, 1977), and was .91 in the K-CES-D. In this study, it was .93.

The State–Trait Anxiety Inventory

The Stait-Trait Anxiety Inventory (STAI) was developed to evaluate an individual's state and trait anxiety level by Spielberger and colleagues (1970). Each subscale of the inventory consists of 20 items. Both subscales are responded to on a four-point Likert scale, with one corresponding to "not at all" and four corresponding to "very much so". This study used the Korean version of STAI, validated by Kim (1978). The scale's Cronbach's α ranged from .86 to .95 in Speilberger et al. (1983). The studies using the Korean version of STAI for university students reported Cronbach's α as .92 (Hahn, 1996) and .93 (Yoon & Chang, 2019). and in our study, it was found to be .93.

Statistical Analysis

Estimating network

We estimated and visualized the network via a Graphical Gaussian Model (GGM) using the R package qgraph (Epskamp et al., 2012). Each node represents the variables (i.e., intolerance of uncertainty, state anxiety, and depression), and the edges indicate partial correlations between the two nodes. To minimize the number of spurious edges, GGMs of the network were regularized via a 'least absolute shrinkage and selection operator (LASSO; Friedman et al., 2008)' with the 'extended Bayes information criterion (EBIC)'. This process reduces all network edge values, some being shrunk to zero, thereby constructing a parsimonious network. Moreover, we utilized the R package bootnet (Epskamp et al., 2018), to conduct difference tests for edge weights and centrality indices of nodes and test the stability of all centrality indices and edge weights. To ensure the stability of each centrality index, the centrality stability coefficient (CS-coefficient) was calculated using case-dropping subset bootstrap, which compares centrality indices based on the subset of data from those based on the complete data. The CS coefficient indicates the maximum proportion of cases that can be eliminated while ensuring a 95% probability that the correlation between the original network's centrality indices and networks' centrality indices based on subsets is 0.7 or higher (Epskam et al., 2018). In addition, CS-coefficient should be at least 0.25 to reliably interpret the network structure and its centrality indices (Epskamp et al., 2018).

Community detection

We subsequently utilized exploratory graph analysis (EGA; Golino & Epskamp, 2017) to estimate and visualize the communities of nodes in a network using the R package EGAnet. Community refers to the dimension within a network, and through EGA, it is possible to identify which node belongs to which dimension. EGA also estimates the network through the graphical EBIC-lasso. After the estimation, EGA uses the Waltkrap community detection algorithm, which obtains communities within the estimated networks.

Results

Partial correlations among IUS items, state anxiety, trait anxiety, and depression are available in Figure 1. The network structure of IU, depression, and state/trait anxiety is shown in Figure 2. Each item of the IUS was included in a network separately, along with the total score of CES-D, STAI-S, and STAI-T as depression ('DPRS'), state anxiety ('ANX_S') and trait anxiety ('ANX_T') respectively. The accuracy analysis revealed a precise estimation of the edges within the network, as evidenced by the narrow bootstrapped confidence intervals observed for each edge (Supplementary Figure 1). Community detection revealed the categorization of variables into

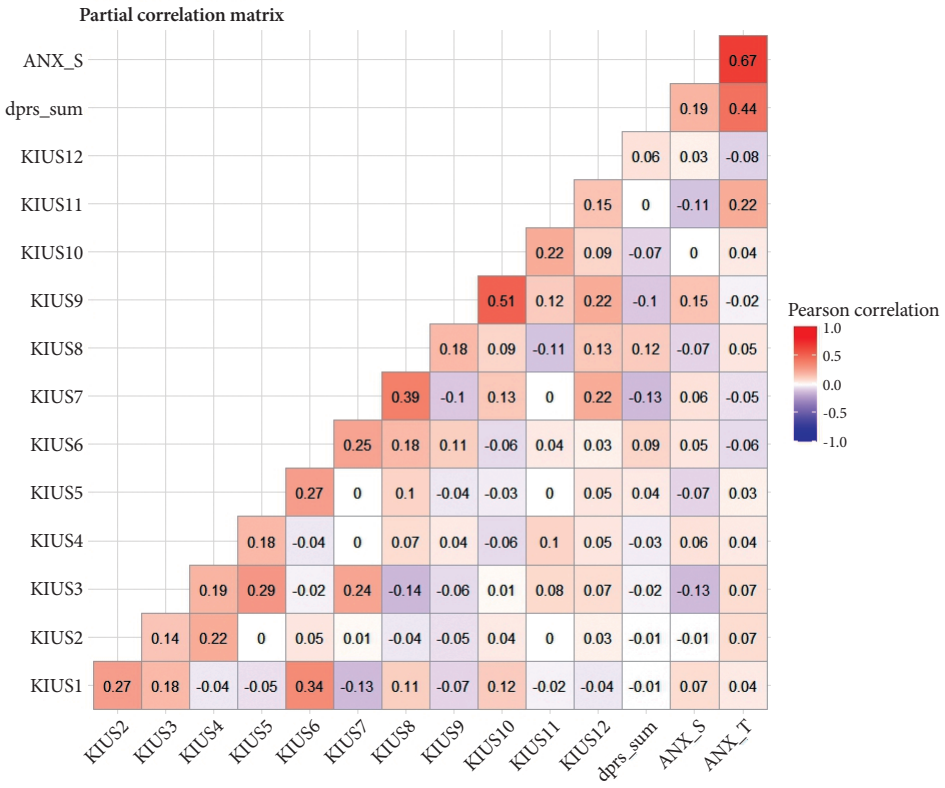

Figure 1. *Partial correlations among IUS items, state anxiety, trait anxiety, and depression.*

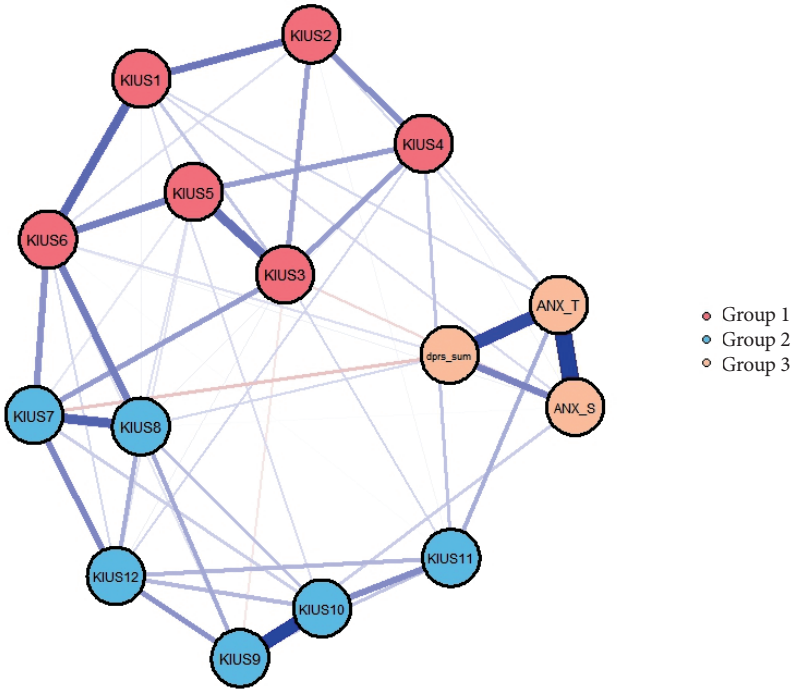

Figure 2. *Network structure of IU, depression, and state/trait anxiety.*
The color of circles (nodes) corresponds to the result of community detection. Blue lines (edges) represent positive correlations, while red lines represent negative correlations. The thickness of the edge shows the strength of the relationship between every two nodes.

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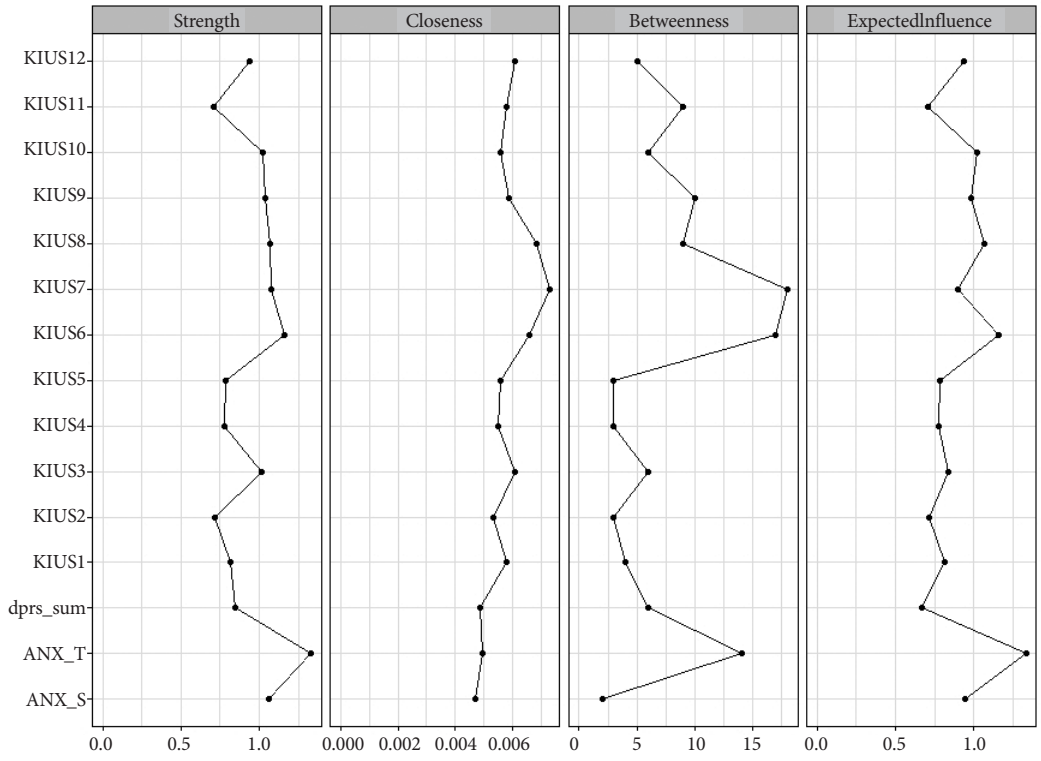

Figure 3. *Four centrality indices (Strength, Closeness, Betweenness, and Expected Influence).*

three distinct groups. Group 1 encompassed IUS items #1, 2, 3, 4, 5, and 6, while Group 2 comprised IUS items #7, 8, 9, 10, 11, and 12. Group 3 comprised the variables depression, state anxiety, and trait anxiety.

Most IUS items, state/trait anxiety, and depression nodes shared positive edges. However, IUS item #3 ('One should always look ahead to avoid surprise') and IUS item #9 ('When it's time to act, uncertainty paralyzes me') showed a negative association. In contrast, all other items within the IUS demonstrated a positive association.

Additionally, some IUS items demonstrated negative edges with either depression or anxiety. To be more precise, Item #3 on the IUS exhibited an inverse correlation with state anxiety, while Item #7 ('I should be able to organize everything in advance') showed a negative association with depression. Furthermore, a positive correlation was found between depression and state anxiety, depression and trait anxiety, as well as state anxiety and trait anxiety.

The stability of centrality indices was examined by estimating the correlation-stability (CS) coefficients of each centrality index using a case-dropping bootstrap. In order to interpret the differences among nodes, CS coefficients should be greater than 0.25, with a preference for them to exceed 0.5. Out of the four centrality indices we examined, CS coefficients of both strength and expected influence were 0.673. However, CS coefficients of closeness and betweenness were lower than 0.5, although CS of closeness is slightly above 0.25 (0.283). Thus, this indicates that while the CS coefficient of strength and expected influence can be reliably interpreted, closeness and betweenness should be interpreted with care. The result of the case-dropping bootstrap is available in the Supplementary Figure 2.

Figure 3 demonstrates the four centrality indices. The node strength of IUS item #6 ("I can't stand being taken by surprise") was the highest among IUS items. However, this node strength was not significantly different from that of IUS items #3, #7, #8, #9, and #10, suggesting that they are similarly connected to other nodes within the network in terms of strength. Moreover, the node strength of trait anxiety was higher than that of state anxiety and depression.

To compare the strength measures of state anxiety and trait anxiety, we conducted a bootstrap difference test to determine whether

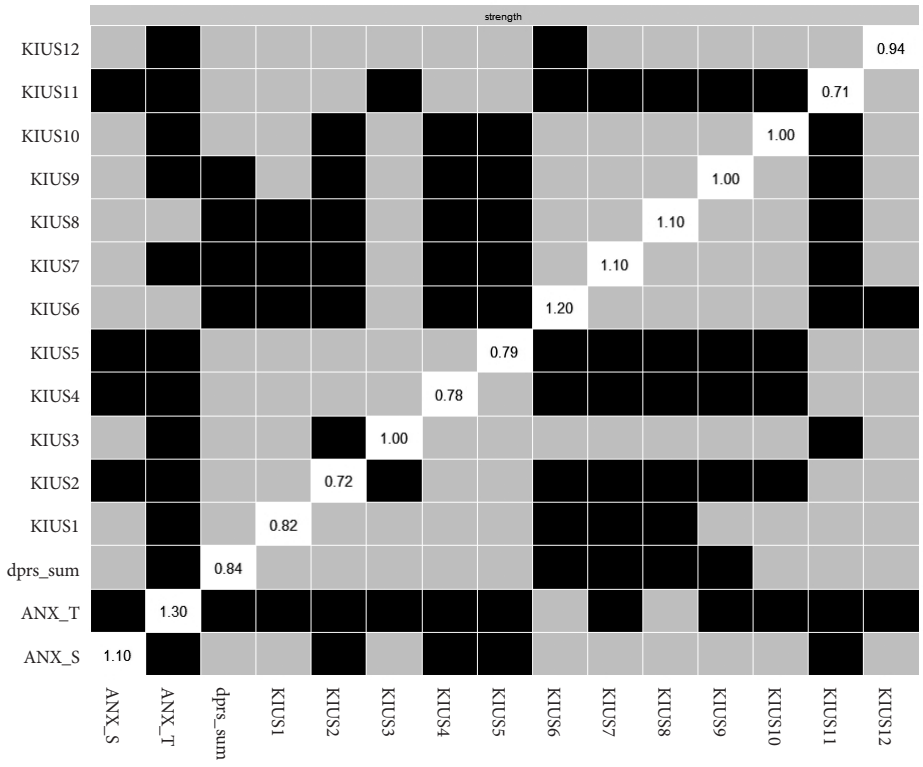

Figure 4. *Bootstrapped difference tests of strength between nodes in the network.*

the observed difference between their strength measures differed significantly from zero. The node strength difference test result appears in Figure 4, while the results of the expected influence difference test and edge strength difference test are available as Supplementary Figure 3. The results revealed that both the strength and expected influence of trait anxiety were significantly higher than those of state anxiety. Additionally, the edge strength difference test indicated that the edge strength between trait anxiety and depression was significantly higher than between state anxiety and depression.

Discussion

This study examined the structure of IU and investigated relationships between IUS items, anxiety, and depression symptoms using network analysis. The finding of this study revealed that IUS item #6 ('I can't stand being taken by surprise') is the most central within the network, suggesting IUS item #6 is most closely related to the rest of the IU scale, depression, and anxiety. This outcome may suggest that individuals with a high level of IU struggle with a cognitive perception of the uncontrollability of future events, leading to psychological/emotional distress. Such psychological/emotional distress could be associated significantly with depression, anxiety, and other IU-related factors, such as behavioral paralysis. While drawing causal relationships between variables solely through network analysis should be avoided (Bottesi et al., 2020; Dablander & Hinne, 2019), focusing on the content corresponding to IUS item #6 appears promising for intervention, as it seems to be beneficial in addressing not only IU but also related symptoms of anxiety and depression considering its high strength.

Moreover, this result aligns with the result of a previous study (Bottesi et al., 2020). In contrast, in another study examining the network composed of IU and symptoms of generalized anxiety disorder, IUS item #2 ('It frustrates me not having all the information I need') turned out to be the most central node in the network (Ren et al., 2021). However, IUS items #2 and #6 have repetitively been classified under the same group as prospective anxiety (Birrel et al., 2011; Carleton et al., 2007; Helsen et al., 2013) or emotional reactions to uncertainty (Bottesi et al., 2020). The concept of prospective anxiety, encompassing both IUS items #6 and #2, in-

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volves fear and anxiety related to expecting uncertainty (McEvoy & Mahoney, 2012), which may represent the cognitive aspect of IU. These support the cognitive-behavioral model of psychopathology, which emphasizes the influence of cognitive content on psychological symptoms. According to this model, one's dysfunctional beliefs and thoughts can causally contribute to depression and anxiety symptoms (Beck, 1976). Therefore, it is suggested that beliefs indicating an inability to cope with uncertainty and expecting catastrophic outcomes may play a pivotal role in exacerbating depression and anxiety symptoms.

The result of our study showed that IU is categorized into two subgroups, showing nearly identical results, albeit slightly different from a previous study (Carleton et al., 2007). Notably, in contrast to prior research, our study demonstrated that IUS item #7 ('I should be able to organize everything in advance') falls within the group comprising IUS items previously categorized under inhibitory anxiety (Carleton et al., 2007). This finding suggests the necessity for a more refined classification considering the behavioral, cognitive, and emotional aspects of IU.

We assume that this finding reflects the risk aversion tendency exhibited by undergraduate students. Item #7 can be interpreted as an inclination to avoid future uncertainty, as well as a propensity to refrain from engaging in uncontrollable situations when faced with future uncertainty. Several studies have documented a growing trend toward risk aversion in various domains, including investment and life decision-making in the COVID-19 situation (Yue et al., 2020; Harrison et al., 2020; Li et al., 2021). This tendency may be linked to a reluctance to take risks and confront new challenges. Furthermore, undergraduate students, often considered to be in the stage of emerging adulthood, contend with considerable instability, including identity exploration, and seeking employment (Arnett, 2015). Faced with life-altering decisions fraught with uncertainty, these students may opt for risk avoidance and safety-seeking, thereby inhibiting action when confronted with highly uncertain situations. Given these characteristics of undergraduate students, it is plausible that item #7 ("I should be able to organize everything in advance") could be perceived as indicative of an inhibitory perspective.

Furthermore, the results of our study indicated a negative correlation between IUS item #3 ('One should always look ahead so as to avoid surprises') and IUS item #9 ('When it's time to act, uncertainty paralyzes me'). This finding suggests that there is heterogeneity between factors in IU. According to results examining the factor structure of IU, IUS items #3 and #9 were categorized into different dimensions (Bottesi et al., 2020; Carleton et al., 2007). Similarly, in the three-factor model of IU, IUS item #3 is grouped under negative beliefs about uncertainty, while IUS item #9 falls under behavioral reactions to the uncertainty. This consistent pattern suggests the existence of heterogeneity among individuals with the same level of IU. In other words, even if individuals have the same level of IU, those who harbor more negative beliefs about uncertain situations may tend to engage in preventive behaviors, even when considering the negative contents of beliefs.

In addition, some IUS items were negatively related to either depression or anxiety, suggesting that IU may be adaptive in particular contexts. Specifically, IUS item #3 was negatively related to state anxiety, and item #7 ('I should be able to organize everything in advance') was negatively associated with depression. Past studies have shown that both of these two items belonged to the same factor, showing their conceptual relevance (Bottesi et al., 2020; Carleton et al., 2007). Our result is also in line with the previous studies in that only those two items were negatively related to internalizing disorders, and the correlation between the two was significant.

Then which characteristics of the two items explain such a negative association with internalizing disorders? Firstly, information-seeking on future events, represented by IUS item #3, may mitigate an individual's level of anxiety. Anxiety is a response triggered by the anticipation of a possible threat and is especially marked by perceptions of uncontrollability and unpredictability of the future event (Barlow, 2002). Thus, seeking information related to facing a situation may help an individual increase sense of control, thereby reducing one's anxiety (Charpentier et al., 2022). However, this effect of reassurance is often temporary, so individuals may get caught in an information-seeking spiral whenever they want to be comforted (Te Poel et al., 2016). Also, while seeking information repetitively, one may encounter negative information as well, which may lead to catastrophizing their situation. Our findings align with previous research, as IUS item #3 exhibited a negative correlation with state anxiety but not with trait anxiety.

This implies that seeking information may not be a foolproof remedy for completely alleviating trait-level anxiety but rather a temporary solution for easing state anxiety. Second, IUS item #7 pertains to organizing future events, an ability that may be compromised in individuals experiencing depression. Depressed individuals generally exhibit lower energy levels, have difficulty concentrating, and may even experience impaired performance on tasks requiring executive functioning (Alves et al., 2014). As a result, the severity of depression can be negatively correlated with the intention to organize future events, as shown by the findings of this study.

In addition, when considering these two results above, it can be assumed that anxiety and depression differ to some degree despite their high comorbidity rate, as previous literature suggests (Anderson & Hope, 2008; Clark & Watson, 1991). According to our findings, anxiety and depression mostly share positive edges with IU, supporting past studies that indicate IU as a transdiagnostic risk factor (McEvoy et al., 2019). However, our findings also highlight differences between anxiety and depression by showing that they share negative edges with different items of IU.

In sum, some aspects of IU can be adaptive according to the result of this study. However, to our knowledge, this study is among the first to address potential positive aspects of IU. Although no study directly examined the positive aspects of IU, this can be assumed by considering the conceptual relevance between IU and perfectionism. Previous literature has demonstrated a close relationship between intolerance of uncertainty and perfectionism (Brosof et al., 2019; Buhr & Dugas, 2006; Reuther et al., 2013; Shikatani et al., 2016). Although perfectionism is generally considered maladaptive (Frost et al., 1993), some evidence suggests its adaptive value (Stoeber & Otto, 2006; Suh et al., 2017; Wigert et al., 2012). In particular, high standards about oneself were related to positive outcomes such as higher levels of extroversion, conscientiousness, positive affect, active coping styles, and academic performance, among various facets of perfectionism (Macedo et al., 2014). Those who have high standards for themselves attempt to achieve mastery and extend their capabilities, which in turn leads to increased happiness. Future studies should examine further the adaptive value of IU and also the possible interaction between IU and perfectionism on possible outcomes.

Furthermore, our findings indicate that both state and trait anxiety exhibited high node strength in the network, which is consistent with prior research demonstrating the relationship between IU and both state anxiety (Oglesby et al., 2017) and trait anxiety (Jensen et al., 2016). However, our study expands upon the existing literature by revealing that the node strength and expected influence of trait anxiety are significantly higher than those of state anxiety. This finding supports the notion of considering IU as a trans-situational variable (Mahoney et al., 2012). Also, we observed that the edge strength between trait anxiety and depression was significantly stronger than that between state anxiety and depression. A recent meta-analysis revealed that trait anxiety measured by STAI scores was strongly related to both anxiety and depression, and individuals with a depressive disorder had even significantly higher scores than those with an anxiety disorder (Knowles & Olatunji, 2020).

Our results further highlight the close relationship between depression and trait anxiety. Additionally, according to our results, while most of the edges did not significantly differ from each other in terms of strength, one edge between IUS item #11 ('The smallest doubt can stop me from acting') and trait anxiety was stronger than some edges. This implies a marginally stronger connection between inhibitory anxiety, which IUS item #11 represents, and trait anxiety. However, if the association between inhibitory anxiety and trait-level anxiety is stronger than that between prospective anxiety and trait-level anxiety, it may indicate the need for more comprehensive and targeted interventions, both qualitatively and quantitatively, for individuals with higher levels of inhibitory anxiety. Further investigation of the relationship between each dimension of IU and other psychological variables is needed for settling specific treatment goals in clinical settings.

This study elucidated the clinical implications of interventions targeting IU, depression, and anxiety symptoms. When developing a therapeutic plan for individuals with high levels of IU, it is essential to identify the specific factors within IU that contribute to the development of symptoms, as IU comprises various cognitive and behavioral facets. Moreover, the result underscores the necessity of targeting cognitive aspects related to uncertainty in individuals with high levels of depression, anxiety, and IU. This entails assisting individuals in cultivating greater tolerance for

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distress arising from uncertain situations. Cognitive-based therapy (CBT) or Acceptance and Commitment Therapy (ACT) are potential treatment modalities for individuals with heightened IU. Similar to mindfulness interventions that foster non-judgmental awareness of present states and perceptions (Kabat-Zinn, 2005), mitigating biased self-perceptions may enhance individuals' capacity to tolerate and accept negative emotional states (Riley & Kalichman, 2015). A meta-analysis investigating IU and emotion regulation strategies found that mindfulness exerted a substantial impact on IU (Sahib et al., 2023). Integrating cognitive restructuring and ACT components to facilitate distress tolerance pertaining to uncertainty is meaningful for individuals experiencing elevated levels of depression and anxiety.

Furthermore, our study unveils the potential adaptive function of IU. These findings suggest that when implementing therapy targeting IU, interventions should prioritize the promotion of adaptive components of IU rather than simply reducing IU levels. This approach can facilitate individuals with heightened IU in establishing appropriate treatment goals and embracing their psychological states more effectively. Rather than regarding IU as a trait to be entirely eradicated, individuals can recognize it as a spectrum wherein both extremes can impair daily functioning.

Finally, the current study is one of the few that examines the relationship between IU, anxiety symptoms, and depression utilizing network analysis. Past literature identified diverse patterns of IU structures in factor analyses and observed variations in the relationship between IU and internalizing symptoms among different cultural and racial populations (Bottesi et al., 2016; Bottesi et al., 2019; Norton, 2005; Yuniardi, 2020) For instance, a previous study demonstrated substantially lower predictive power of IU for generalized anxiety disorder (GAD) in an Indonesian student sample compared to a United Kingdom student sample. In light of such findings, there is a need to develop culturally appropriate interventions that consider potential differences in the interpretation and psychological function of IU. Our study lays the groundwork for the development of IU-targeted interventions suitable for Korean undergraduate students.

Limitations and Suggestions for Future Research

The present study has several limitations. Firstly, the sample size is relatively small, consisting of Korean undergraduate students at a university, which may limit the generalizability of the findings to other populations with different cultural backgrounds.

Also, the dropout rate was evidently observed in our sample. Extant literature have argued that dropout rates in online surveys tend to be higher than those in in-person surveys or experiments (Birnbaum, 2004; Nestler et al., 2015; Hoerger, 2010; Reips, 2002a, 2002b). Unlike off-line survey, participants easily quit the online survey any time prior to completion (BirnBaum, 2004; Reips, 2002a, 2002b), with those who show low interest in the study subject and survey being more likely to withdraw online survey (Galesic, 2006).

Given that undergraduate students majoring in psychology are generally well-acquainted with online survey related to psychology, it is plausible that our survey questionnaires may not have elicited adequate interest. Consequently, substantial respondents may be more inclined to disengage and abandon the survey, thereby contributing to dropout rates. Furthermore, participants might exhibit hesitancy in completing questionnaire due to privacy concerns, given that our study questionnaire ask participants' detailed information such as admission year and major.

Moreover, while the current study's sample size slightly exceeds the recommended minimum sample size of 250 for network analysis, it is crucial to augment the sample size to attain greater statistical power. Therefore, future studies can benefit from a larger sample for detecting meaningful associations and drawing robust conclusions would be enhanced.

Next, gender bias was observed within our sample, with approximately three times as many female participants as male. This skew is partially ascribed to the demographic characteristic of our participants, the majority of whom are pursuing a major in psychology. A longstanding trend reflective of women's higher proclivity toward selecting psychology as their major, as evidenced by several recent studies and reports (Richard, 2015; Ceci et al., 2023; National Center for Education Statistics, 2014). While no significant gender differences were identified in relation to depression, anxiety, and intolerance of uncertainty, there is need for future investigations to recruit participants more equitably across genders to preclude potential overrepresentation or underrepresentation of specific gender groups.

Furthermore, since this study did not target a clinical population, future studies are needed to examine whether the specific aspect of IU is adaptive for the clinical population and the extent to which it is adaptive. Additionally, as this study is cross-sectional, it is not possible to infer causal relationships between Intolerance of uncertainty and depression/anxiety symptoms. Lastly, the current study used self-report measures, which might not be entirely reliable. Future research using network analysis should consider utilizing experimental methods to confirm the causal relationships between various factors of IUS and anxiety levels.

Data Availability Statement

The raw data supporting the conclusions of the article will be made available by the authors, without undue reservation.

Author contributions statement

GL, a graduate student at Yonsei University who currently works as a clinical research coordinator at Gangnam Severance Hospital, collected the data and led the manuscript preparation. GL and YC, also a graduate student at Yonsei University, jointly contributed to study design, data analysis and interpretation, as well as the creation of figures and tables. GL, YC, and JL, another graduate student at Yonsei University, collaborated on data cleaning, preprocessing, and manuscript drafting. SHP, a professor at Yonsei University, served as the principal investigator of the research grant and supervised the research process. All authors provided critical feedback, participated in the revision of the manuscript, and approved the final submission.

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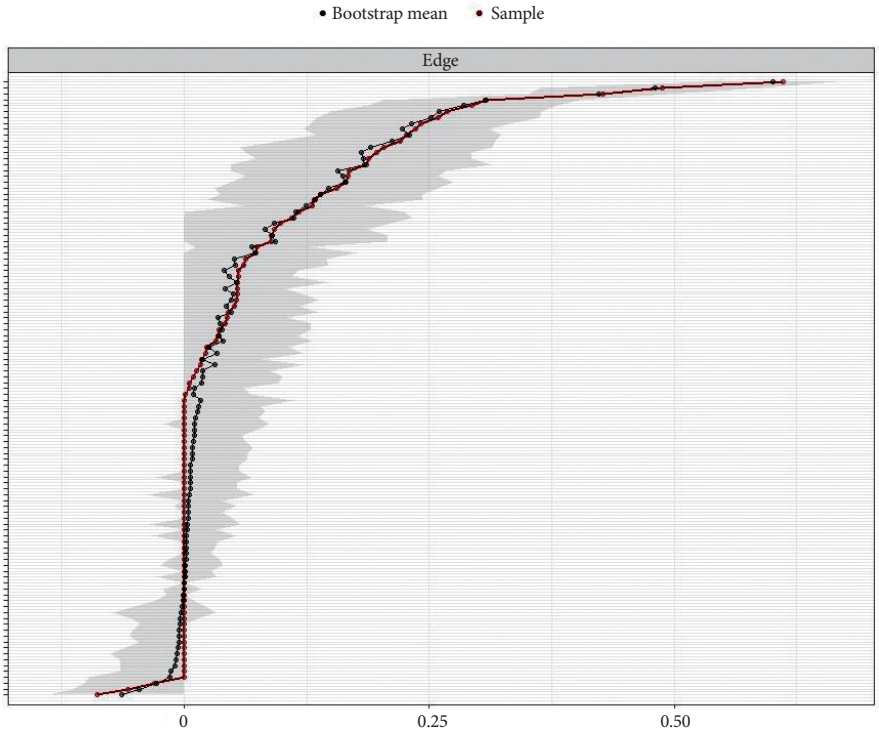
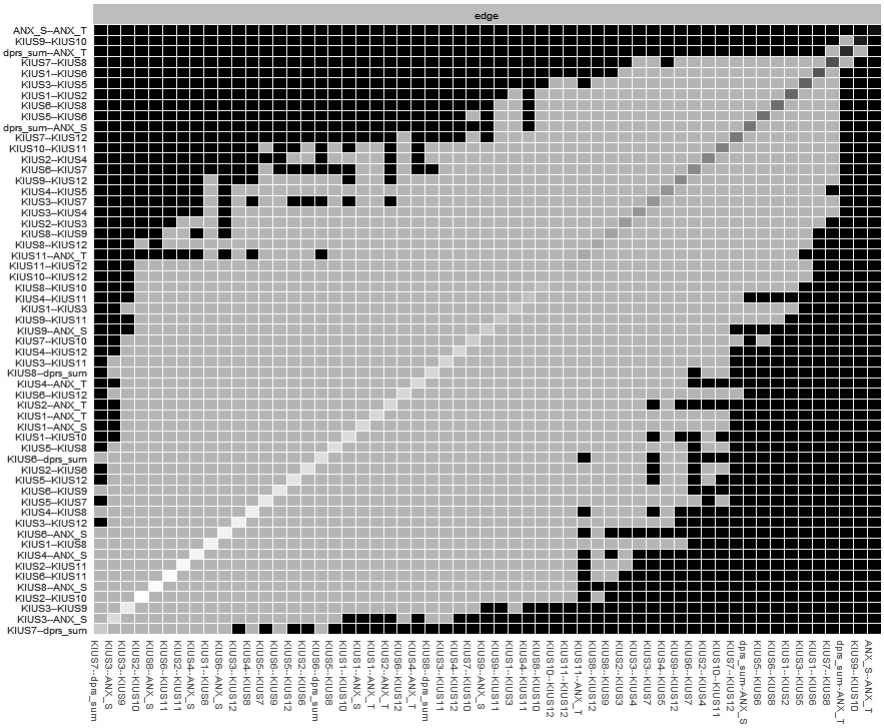


Supplementary Figure 1. *Bootstrapped confidence intervals for the network edge weights.*



Supplementary Figure 2. *Bootstrapped difference tests of strength between edges in the network.*

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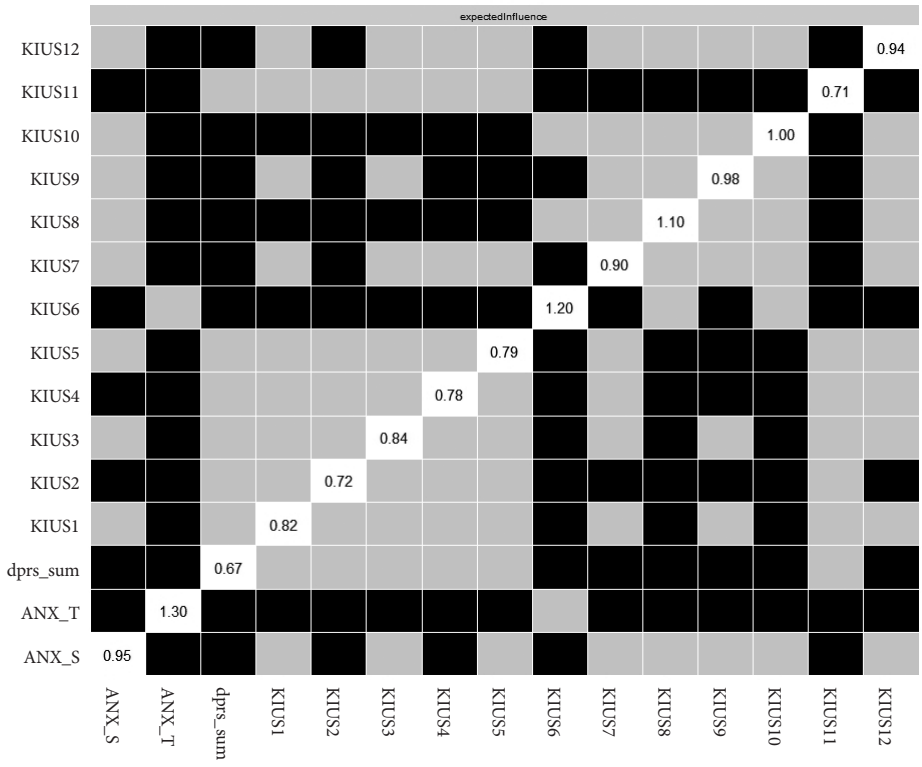
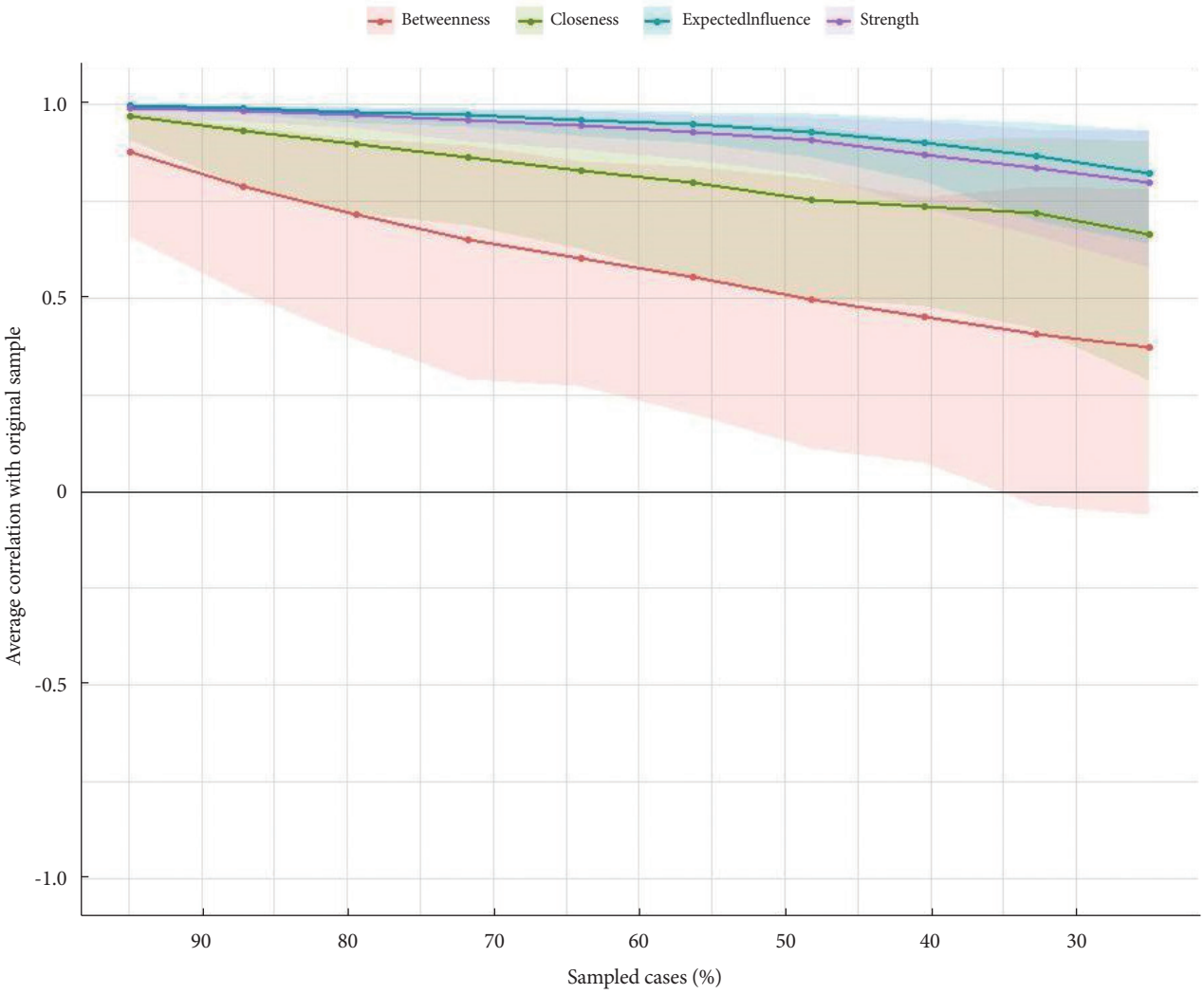


Supplementary Figure 3. *Bootstrapped difference tests of expected influence between nodes in the network.*



Supplementary Figure 4. *Correlation stability plot of centrality indices obtained from case-dropping bootstrap.*

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