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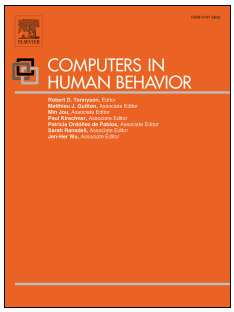

A network analysis approach to the relationship between fear of missing out (FoMO), smartphone addiction, and social networking site use among a sample of Chinese university students

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Credit Author Statement

Conceived and designed the experiments: LL, ZMN. Performed the experiments: LL, ZMN. Analysed and interpreted the data: LL, MDG. Contributed reagents/materials/analysis tools: SLM. Wrote the first draft of the paper: LL, ZMN. Edited and contributed to the revised paper: MDG.

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A network analysis approach to the relationship between fear of missing out (FoMO), smartphone addiction, and social networking site use among a sample of Chinese university students

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A network analysis approach to the relationship between fear of missing out (FoMO), smartphone addiction, and social networking site use among a sample of Chinese university students

Abstract

Background and aims: Previous research has explored the relationship between fear of missing out (FoMO), social network site (SNS) use, and/or smartphone addiction by correlation analysis and construction of latent variables model. However, smartphone addiction may also intensify negative emotion (e.g., fear of missing out, anxiety, and depression) and risky behavior (e.g., excessive social media use and problematic smartphone game activities). To date, few studies have adopted a network analysis approach to investigate the reciprocal action between the aforementioned variables. Therefore, the present study used network analysis to evaluate the relationship between FoMO, SNS use, and smartphone addiction among a sample of Chinese university students.

Methods: A sample comprising 1258 Chinese university students (502 males) completed a survey including the Chinese Trait-State Fear of Missing Out Scale (T-SFoMOSC), Mobile Phone Addiction Index (MPAI), and Social Network Site Intensity Scale (SNSIS).

Results: Inability to control craving and productivity loss had the closest edge

intensity. Feeling anxious and lost was the strongest central node (betweenness = 1.903, closeness = 1.853, strength = 1.287) in the domain-level network. The item-level network analysis showed that FoMO was positively associated with SNS use and smartphone addiction. There were no significant gender differences in the network structure and the global edge strength.

Conclusions: The findings here indicate that there is a close relationship between FoMO, SNS use, and smartphone addiction. Excessive social media use and higher level of FoMO appear to play a contributory role in smartphone addiction. Smartphone addiction may also further increase excessive SNS use and increase the level of FoMO. A bidirectional influence between smartphone addiction, SNS use and FOMO should be considered. Gender differences in FoMO, smartphone addiction, and motivation of SNS use should be investigated in future research.

Keywords: fear of missing out; smartphone addiction; social networking site use; network analysis; Chinese university students

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1. Introduction

Fear of missing out (FoMO) was first described in the context of business decision-making (McGinnis, 2004). More recently, FoMO has been defined as "a pervasive apprehension that others might be having rewarding experiences from which one is absent" by Przybylski et al. (2013, p. 1841). In addition, FoMO is regarded as a specific predisposition (i.e., trait-FoMO) and a specific cognition in online context (i.e., state-FoMO) (Wegmann et al., 2017). Moreover, FoMO has become a popular psychological phenomenon in relation to online social engagement (Alt, 2017). A study by Xinli001 (i.e., a Chinese psychological information website) reported that among social media users (i) more than 15% experience severe FoMO, (ii) nearly one-third frequently checked *Weibo* to avoid to missing out on the latest topics, and (iii) three-fifths feel upset if they are without their smartphone or their smartphone is out of power (Xinli001, 2016).

As of December 2020, the numbers of smartphone users in China totaled 0.986 billion (China Internet Network Information Center [CNNIC], 2020) and 3.5 billion worldwide (statista.com, 2020a). As one of the 'generalized' internet addictions (Montag et al., 2015; Chen et al., 2020), smartphone addiction refers to "an inability by individuals to regulate smartphone use and which leads to negative consequences and clinical impairment in daily life" (Billieux, 2012, p. 299). Although the term 'smartphone addiction' is accepted and used widely by many scholars in behavioral addiction field (e.g., Kwon et al., 2013; Haug et al., 2015; Montag et al., 2021; Barnes, Pressey, & Scornavacca, 2019; Horvath et al., 2020), other scholars prefer the term

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'problematic smartphone use' (e.g., Panova & Carbonell, 2018; Elhai et al., 2020). However, irrespective of terminology, the prevalence of smartphone addiction has been wide ranging. For instance, the following prevalence rates have been reported: 2.7% disordered smartphone users among participants in a multi-country online survey (Hussain, Griffiths, & Sheffield, 2017); 1.0%-3.9% among European young adults (Lopez-Fernandez et al., 2017); 21.3% among Chinese undergraduates (Long et al., 2016); 36.4% among Korean college students (Kim et al., 2017); and 7.5% among Korean middle and high school students (Kim et al., 2019). A recent meta-analysis reported that the median prevalence of problematic smartphone use among child and young people was 23.3% (14.0-31.2%) with studies mainly coming from Asia (Sohn et al., 2019).

Social networking sites (SNSs) are defined as web-based services that allow individuals to construct personal profiles and display and share personal connections within a bounded system (Boyd & Ellison, 2007). SNSs have become highly popular in China and worldwide more generally in recent years. QQ, WeChat and Weibo (a micro blog) are the three most frequently used SNSs among Chinese people. Although SNS use and social media use are not the same (Kuss & Griffiths, 2017), they are often used interchangeably in China because SNSs (i.e., QQ and WeChat) include powerful functions alongside instant messages, such as microblogging, playing music and videos, gaming, and showing photos. QQ and WeChat, both popular instant message platforms, have increasingly attracted the attention of individuals of different ages, gender, and occupational groups (CNNIC, 2020).

According to the CNNIC (2020), the number of users (older than six years) who used instant messaging (IM) services exceeded 0.978 billion (99.3% of smartphone users) in December 2020. The number of QQ and WeChat monthly active users were both more than 980 million by the end of 2020 (Statista.com, 2020b).

Some scholars have indicated that FoMO is related to excessive social networking site usage and SNS addiction (Kuss & Griffiths, 2017; Blackwell et al., 2017; Casale et al., 2018). In addition, problematic smartphone use has also been found to be related to FoMO (Wang et al., 2019; Elhai et al., 2016). Gezgin (2018) investigated the relationship between FoMO, smartphone addiction, and excessive SNS use among Turkish high school students and reported a significant and positive correlation between the three variables.

Although the relationship between FoMO, SNS use and/or smartphone addiction has been studied utilizing correlation analysis or latent class analysis, few studies have used social network analysis as a radically new method of understanding the relationships between these variables. Therefore, network analysis was utilized in the present study to better explain the relationship between FoMO, smartphone addiction, and SNS use among a sample of Chinese university students. A more visual depiction of the variables' associations may help to elaborate the theoretical links between FoMO, smartphone addiction, and SNS use.

2. Theoretical background

2.1 Related theories on the relationship between FoMO, smartphone addiction and SNS use

Self-determination theory (SDT) proposes that individual psychological needs include autonomy, competence, and relatedness (Deci & Ryan, 1985), which may explain the motives for SNS use among adolescents and young adults by who are expressing/presenting themselves through social networking sites/platforms (e.g., photo/video-sharing, sharing internet memes, blogging, etc.), accessing updated information from media or others, and building and maintaining interpersonal relationships, Daily frustration of basic psychological needs and stronger SNS use motivations may lead to high levels of FoMO and excessive smartphone use/smartphone addiction. In addition, people's need to belong is an innate drive which impacts on most individuals' behaviors. Based on the Belongingness Hypothesis (Kim, Wang, & Oh, 2016), individuals may yearn for more communication with others through social media use and/or face-to-face interaction for better integration into the collective. With the development of mobile smart devices, online social activities are easier facilitated and more convenient. In addition, the Interaction of Person-Affect-Cognition-Execution (I-PACE) model also posits that negative affect and cognitive responses may be important factors in developing addictive behaviors (e.g., smartphone addiction and gaming disorder) through the interactions between multiple variables (Brand et al., 2019). Moreover, Billieux (2012) posited that the pathway of problematic mobile phone use included the reciprocal influence between negative affect and executive function (i.e., poor self-control), which may cause problematic mobile phone/smartphone use. In turn, negative outcomes from excessive or uncontrolled mobile phone use also may increase

negative affect (FoMO, depression and anxiety) and impulsive SNS use or gaming.

2.2 Network analysis

Network analysis has been used widely in the fields of natural science and social science over the past two decades, and is characterized by "structure, positions, and dyadic properties and the overall 'shape' of ties on graph-theoretic properties" (Borgatti et al., 2009, p 894.). Network analysis can quickly establish a relationship model between numerous variables and provide the possibility of exploring complex psychological systems. Moreover, network analysis focuses on how variables relate to each other and reveals data models which are difficult to show when utilizing latent variable models. The interaction of variables may be a more suitable explanation to the occurrence and development of some social phenomena or disease symptoms. The core idea is that an episode of mental disorder originates from causal interactions between symptomatic elements has resonated with some clinical scientists. This has led to the social network analysis approach being applied widely to psychopathology (McNally, 2021). Structural equation modeling (SEM) and principal component analysis (PCA) are mainly used to study latent variables and have explicit direction rather than reciprocal action between variables. Furthermore, network analysis can be used to study different time nodes of observed variables and its process of change over time through longitudinal study (Schmittmann et al., 2013).

For instance, Isvoranu et al. (2016) used a longitudinal network analysis to examine the relationship between childhood trauma and psychotic symptoms, and

reported close connections between all types of childhood trauma and positive and negative psychotic symptoms through symptoms of general psychopathology. The use of network analysis helped investigate and identify pathways that were involved in the relationship between childhood trauma and psychosis, and which may be helpful in mapping potential trans-diagnostic processes. In a different study, network analysis of dark personality traits indicated that callousness and interpersonal manipulation were central traits in the dark personality network. The benefit of network analysis was in using a graphical and quantitative method which may better describe the centrality of dark personality traits (Marcus, Preszle, & Zeigler-Hill, 2018). In addition, social network analysis has been utilized to demonstrate that social anxiety disorder is a densely interconnected network of fear and avoidance in social situations, which was consistent with the network theory of mental disorders (i.e., that networks with strong symptom connectivity were considered as more pathogenic than networks with weaker connectivity) (Heeren & McNally, 2018). The network analysis used here was the first study in this area to adopt graph theory to visually verify the core concept of social anxiety disorder.

Some scholars have carried out research into smartphone addiction and FoMO on graph theoretic approach, respectively. For example, Andrade et al. (2020) validated the Brazilian short version of Smartphone Addiction Scale (SAS-SV) and found that withdrawal and preoccupation symptoms had the strongest influence in the smartphone addiction network when presented visually. Huang et al. (2021) explored the network of problematic smartphone use and found that loss of control was the

key feature of this construct, which suggests preventive actions focused on self-regulation. In addition, in relation to the Big Five personality traits, FoMO was positively associated with neuroticism and negatively correlated with agreeableness, conscientiousness, extraversion and openness based on exploratory graph analysis (EGA), and which investigated the relationship between FoMO and personality at a more detailed level (Rozgonjuk et al., 2021). However, there is a lack of research on the relationship between FoMO, smartphone addiction, and SNS utilizing networking analysis.

3. Hypotheses development

3.1. The relationship between FoMO and smartphone addiction

Higher levels of FoMO may also contribute to addictive behaviors (e.g., internet addiction, gaming disorder, and impulsive buying) (Pontes, Taylor, & Stavropoulos, 2018; Long et al., 2019; Wang et al., 2019; Yuan, Elhai, & Hall, 2021; Aydin et al., 2019). A significant positive correlation between FoMO and problematic mobile phone use was found among Turkey high school students (Coskun, & Muslu, 2019). In addition, Wolniewicz et al. (2018) also indicated that FoMO was strongly related to problematic and social smartphone use. Moreover, among adolescents, sensation seeking was reported as a predictor of smartphone addiction in which FoMO and procrastination have been identified as mediators (Wang et al., 2019). However, cross-lagged findings of the relationship between FoMO and smartphone addiction has not received support at different time-points (Coco et al., 2020).

H1. FoMO will be positively associated with smartphone addiction.

3.2. The relationship between FoMO and SNS use

Some studies have reported that individuals with low psychological need satisfaction (Oberst et al., 2017; Przybylski et al., 2013; Xie et al., 2018) and who use social media frequently (Andreassen et al., 2016; Błachnio & Przepiorka, 2018; Primack et al., 2017) experience severe FoMO. Roberts and David (2020) reported that FoMO had a positive indirect effect on social connection via social media intensity. In a longitudinal study, Buglass et al. (2017) indicated that SNSs may impact on online vulnerability through FoMO and that decreased self-esteem may facilitate a potentially detrimental cycle of FoMO-inspired SNS use. In addition, recent meta-analyses have reported a positive association between FoMO and SNS use, as well as between FoMO and problematic SNS use (Fioravanti et al., 2021; Zhang, Li, & Yu, 2021). Some scholars have also reported that FoMO is associated with social media addiction utilizing cross-sectional research (Blackwell et al., 2017; Elhai et al., 2016).

H2. FoMO will be positively associated with SNS use.

3.3. The relationship between smartphone addiction and SNS use

Excessive smartphone use has been associated with addiction to social networking site use (Cha, & Seo, 2018; Haug et al., 2015; Barnes, Pressey, & Scornavacca, 2019). Investigations into SNS use has also stimulated important research for scholars in the field of behavioral addiction. For example, a survey of Taiwanese children reported that excessive SNS use may increase the risk of smartphone addiction (Chang et al., 2019). In addition, Noë et al. (2019) indicated that the excessive use of social media

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apps generally was associated with smartphone addiction. Moreover, in another study, SNS use, game use, and entertainment-related use were positive predictors of smartphone addiction, while SNS use may better predict smartphone addiction than game use among elementary school students in South Korea (Jeong et al., 2016).

H3. Smartphone addiction will be positively associated with SNS use.

3.4. FoMO, smartphone addiction and SNS use

The rapid growth of the internet has increased interpersonal communication among individuals. However, overuse of the internet may also result in some negative outcomes for a minority of individuals, including smartphone addiction and gaming disorder, as well as negative emotional states (e.g., FoMO, depression, and anxiety). In addition, excessive social media users may spend less and less time offline to participate in real-life activities (Duvenage et al., 2020), which can cause FoMO when they are not online. Moreover, among Chinese adolescents, social media use has also given rise to upward social comparisons, in which FoMO and daily duration of SNS use on smartphones were risk factors for smartphone addiction and FoMO was associated with SNS addiction among Chinese adolescents (Yin et al., 2019). In a study of Turkish university students, a significant positive association between Facebook intensity, FoMO, and smartphone addiction was reported, with FoMO and smartphone addiction possibly being predictive of Facebook intensity (Traş & Öztemel, 2019). Another study reported a bidirectional relationship between compulsive internet use and psychological problems, especially the reciprocal relationship between mobile phone addiction and depression (Van den Eijnden et al.,

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2008; Jun, 2016; Billieux, 2012). These previous studies suggest a complex interactive relationship between SNSs, FoMO, and smartphone addiction.

H4. There will be a close and reciprocal relationship between FoMO, SNS use, and smartphone addiction.

3.5 Gender differences in FoMO, smartphone addiction and SNS use

Przybylski et al. (2013) reported that males had higher levels of FoMO than females, while some studies have reported the opposite or no gender differences at all (Stead & Bibby, 2017; Beyens, Frison, & Eggermont, 2016; Tomczyk & Selmanagic-Lizde, 2018). Gender differences in FoMO need to be examined. Studies have reported females with smartphone addiction used more multimedia application and problematic SNS use was associated with depression, anxiety, and sleep problems and being more responsive to internal motives, whereas males were more sensitive to external motives and used more gaming apps which were associated with anxiety and sleep problems (Chen et al., 2017a, 2017b). Moreover, motivation of SNS use has been found to be significantly different between gender, with females using SNSs to gain social information and males using them to gain general information (Krasnova et al., 2017). Blomfield Neira and Barber (2014) found that compared with male adolescents, female adolescents reported more negative indicators (e.g., depressed mood and low self-esteem) in relation to their SNS use. Moreover, females give and receive greater social support than men (Tifferet, 2020). Considering the inconsistencies in FoMO, smartphone addiction, and SNS use in relation to gender, the structure network and the global strength among gender

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groups was compared.

H5. There will be gender differences in the network structure and the global strength among Chinese university students.

4. Methods

4.1. Participants and procedure

The present study adopted a cross-sectional design and comprised a sample of 1258 university students from two provinces in China by utilizing convenience sampling. An online survey was completed by participants on the *Wenjuanxing* platform (a popular Chinese survey website). After excluding participants providing incomplete data, 1143 participants remained for analysis (502 males [43.9%] and 641 females [56.1%]). All participants owned a smartphone and used social media. The mean age of participants was 20.2 years (SD = 1.6, aged 18 to 25 years). From October 2019 to April 2020, participants were recruited from three universities (731, 418 and 298 participants, respectively) in Jiangxi and Liaoning provinces. The participants completed the survey for course credit after a detailed explanation of the research purpose. The online survey took approximately five minutes to complete.

4.2. Measures

Chinese Trait-State Fear of Missing Out Scale (T-SFoMOSC)

The Trait-State Fear of Missing Out Scale (T-SFoMOS; Wegmann et al., 2017)

assesses the level of fear of missing out and the Chinese version of T-SFoMOS was validated by Li et al. (T-SFoMOSC, 2020). The T-SFoMOSC includes 12 items and two factors, comprising trait-FoMO (e.g., *"I fear others have more rewarding experiences than me"*) and state-FoMO (e.g., *"I continuously consult my smartphone, in order not to miss out on anything"*), which is consistent with the original T-SFoMOS. Each item is assessed on a five-point Likert scale from 1 (*totally disagree*) to *5* (*totally agree*). A higher total score indicates a higher level of FoMO. The Cronbach's alpha and McDonald's ω in the present study were 0.82 and 0.82 (total scale), 0.76 and 0.78 (trait-FoMO), and 0.79 and 0.80 (state-FoMO).

Mobile Phone Addiction Index (MPAI)

The Mobile Phone Addiction Index (MPAI) (Leung, 2008) assesses the severity of smartphone addiction and the Chinese version was validated by Huang et al. (2014). The MPAI has 17 items with four factors, comprising inability to control craving, feeling anxious and lost, withdrawal/escape, and productivity loss. Each item is assessed on a five-point Likert scale from 1 ("*not at all"*) to 5 ("*always"*). Higher total scores indicate higher severity of smartphone addiction. The Cronbach's alpha and McDonald's ω of the total MPAI were 0.86 and 0.86 in the present study. The Cronbach's alpha and McDonald's ω for inability to control craving were 0.75 and 0.76, 0.74 and 0.76 for feeling anxious and lost, 0.72 and 0.77 for withdrawal/escape, and 0.71 and 0.75 for productivity loss.

Social Network Site Intensity Scale (SNSIS)

The SNSIS assesses SNS intensity, and was adapted from the Facebook Intensity

Scale (Ellison, Steinfield, & Lampe, 2007) and the Chinese version was validated by Sun et al. (2016). The SNSIS contains eight items, two items of which assess the extent of SNS activities among participants (i.e., "*About how many total SNSs [e.g., QQ or Wechat] friends do you have*?"[SNSI1; 1 = "10 or less", 2 = "11～50", 3 = "51～100", 4 = "101～150", 5 = "151～200", 6 = "201～250", 7 = "251～300", 8 = "301～400", 9 = "more than 400"] and *"In the past week, on average, approximately how many minutes per day have you spent on SNSs"* [SNSI2; 1 = "less than 10 minutes", 2 = "10～30 minutes", 3 = "31～60 minutes", 4 = "1～2 hours", 5 = "2～3 hours", 6 = "more than 3 hours"]) and the other six items assess individual attitude to SNS activities (SNSI3; e.g., "*I would be sorry if SNSs [e.g., QQ or Wechat] shut down*"). The six items are assessed on a five-point Likert scale from 1 ("*totally disagree"*) to 5 ("*totally agree"*). Higher total scores indicate higher intensity of SNS use. In the present study, the Cronbach's alpha and McDonald's ω for the total SNSIS were .74 and .80, respectively.

4.3. Statistical analysis

Descriptive statistics, Pearson's correlation and eta-squared (η^2) were performed using SPSS 25. The Cronbach's alpha, McDonald's ω, Cohen's *d*, Bayesian correlation, and network analysis were conducted using JASP (Jeffrey's Amazing Statistics Program). The network comparison test (NCT) was adopted using the R package (van Borkulo, 2016).

Visualized network analysis was performed in the present study. A graphical least

absolute shrinkage and selection operator (LASSO; Friedman et al., 2008) regularization based on the Extended Bayesian Information Criterion (EBIC; Chen & Chen, 2008), called the EBICglasso model and calculated using JASP. The tuning parameter was set to 0.5 for a more parsimonious and easier explainable network (i.e., fewer edges, higher specificity and sensitivity). The centrality of codes in the network represented study variables, which were calculated including betweenness (degree of connectivity), closeness (the distance centrality), and strength (degree centrality) (Epskamp et al., 2012). Correlation stability coefficient (*CS*-coefficient) was used to describe the node centrality stability, which was suggested to be preferably above 0.5 for interpretability and stability (Epskamp et al., 2018). The connection of codes was described using edges. Stronger correlation and weaker correlation were drawn by thicker edges and thinner edges, respectively. Bootstrapped 95% confidence intervals were utilized for estimating edge stability (the number of bootstrap samples is 1000) and fewer overlaps indicate higher stability. The structure network and the global network strengths were compared across gender utilizing the network comparison test (NCT).

4.4. Ethics

The study was approved by the research team's University Research Ethics Committee, and all procedures were performed in line with the Declaration of Helsinki. All participants provided oral informed consent.

5. Results

5.1. Descriptive statistics and correlation analyses

Descriptive statistics and groups comparison for the study variables are shown in Table 1. The SNS use scores were significantly different for gender (t = 2.79, p = 0.005) and grades (F = 4.63, p = 0.003). However, the effect sizes for gender (Cohen's d = 0.166) and grade (η^2 = 0.012) were both small (i.e., less than 0.20).

As shown in Table 2, total scores on FoMO, state-FoMO, and smartphone addiction scales were significantly positively associated with SNS use (All p <. 01). Trait-FoMO and four factors of smartphone addiction were significantly positively associated with SNS use (p <. 01) except for Item SNSI1 (numbers of SNS friends) (p >. 05). The correlation coefficients of state-FoMO with SNS use, smartphone addiction, and total FoMO were higher than those of trait-FoMO with SNS use, smartphone addiction, and total FoMO. The Bayesian correlation test found that most of log(BF_{10}) were more than 3. The effect sizes of the relationship between FoMO, smartphone addiction, and SNS use were verified effectively by Bayesian correlation analysis.

5.2. EBICglasso network analysis

The EBICglasso network including trait-FoMO, state-FoMO, SNS use (total score on the SNSIS), and four factors of smartphone addiction for the 1143 university students are presented based on the domain-level network in Figure 1A. There were seven nodes and 18 non-zero edges in the network. Nodes S1 (inability to control craving) and S4 (productivity loss) had the strongest edge intensity (r = 0.43). Node F2

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(state-FoMO) had a direct association with the intensity of SNS use (r = 0.28), F1 (trait-FoMO, r = 0.28), and S2 (feeling anxious and lost, r = 0.23). Node S2 had a direct association with S3 (withdrawal/escape, r = 0.26), S1 (r = 0.21), and intensity of SNS use (r = 0.16). Item-level FoMO, smartphone addiction, and SNS use data are shown in Figure 1B. The network analysis showed that FoMO was positively connected with SNS use and smartphone addiction.

In the domain-level network, the edge stability estimation showed that fewer overlaps indicated a moderate stability of the network (Appendix S1). The *CS*-coefficients of trait-FoMO, state-FoMO, SNS use, and four factors of smartphone addiction including inability to control craving, feeling anxious and lost, withdrawal/escape, and productivity loss were 0.50, 0.93, 0.55, 0.80, 0.97, 0.72, and 0.71, respectively (Appendix S2). The centrality stability of nodes was considered preferable in the network (i.e., all $CS \geq 0.5$). Table 3 and Figure 2 shows the study variables' betweenness, closeness and strength (degree) for the 1143 university students. S2 was the most central node and had the strongest betweenness (1.903) and closeness (1.853), as well as the highest level of strength centrality (1.287).

In the item-level network, items s10 (*"You feel anxious if you have not checked for messages or switched on your mobile phone for some time"*) and s14 (*"You have used your mobile phone to talk to others when you were feeling lonely"*) had higher level of strength centrality (1.893 and 1.45) in smartphone addiction. Items x6 (*"I am continuously online in order not to miss out on anything"*) and x7 (*"It is important that I have a say about the latest issues in my online social networks [videos, images,*

posts, etc.]") had higher level of strength centrality (1.624 and 1.417) in FoMO, while y8 (*"I would be sorry if SNSs shut down"*) had the highest level of strength centrality (0.938) in SNS use (Appendix S3).

5.3. EBICglasso network analysis for gender

Nodes S1 and S4 had the strongest edge intensity among males (r = 0.41) and females (r = 0.42). S2 had the strongest betweenness, closeness, and strength among males (1.668, 1.872, and 1.586). For females, S2 also had the strongest betweenness (1.903 and 1.816) and closeness (1.777 and 1.720), and state-FoMO had the highest strength coefficient (1.277). (Appendix S4 and S5).

5.4. Comparison of network between gender

The network comparison test (NCT) showed the network structure had no significant difference between males and females (M = 0.106, p = 0.66). The edge invariance test was not conducted to avoid an increased Type I error when the network structure is invariant (i.e., the NCT proved slightly too liberal for the edge strength test relative to the network structure invariance test) (van Borkulo et al., 2017). The network comparison test (NCT) showed the global edge strengths had no significant difference among gender group (males = 2.447 vs. females = 2.536, p = 0.696).

6. Discussion

The present study examined gender differences for FoMO, SNS use, and smartphone addiction (using t-tests alongside effect sizes). The results were consistent with Tomczyk and Selmanagic-Lizde' (2018) who reported that FoMO was

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not associated with gender. Some studies have indicated that males and females have different motives concerning SNS use for self-presentation (e.g., Huang, Kumar, & Hu, 2018). However, there was no significant difference between males and females in relation to their SNS use in the present study. Moreover, the present study found there was no gender difference concerning smartphone addiction, which was similar to Chen et al.'s (2017) findings among Chinese medical college students.

There were significant positive associations between smartphone addiction and FoMO and SNS use. These results supported Hypotheses 1-3, which concur with Gezgin (2018). FoMO and SNS use may better predict than duration of smartphone ownership smartphone addiction, and FoMO was the strongest predictive variable for smartphone addiction among high school students in a Turkish study (Gezgin, 2018). Significant positive associations between FoMO, smartphone addiction, and Facebook intensity have also been reported among Turkish university students (Traş & Öztemel, 2019). A recent study also indicated that FoMO was related to problematic use of WhatApp, Facebook, Instagram, and Snapchat (Rozgonjuk et al., 2020). In addition, state-FoMO had higher correlation coefficients with other variables than trait-FoMO in the present study. These findings are similar to those of Balta et al. (2020) who reported significant associations between state-FoMO and problematic Instagram use and trait-FoMO and problematic Instagram use.

As emerging adults, Chinese university students regard social network sites (mainly QQ, WeChat and Weibo) as part of their daily lifestyle. SNS use may facilitate interpersonal communication, provide entertainment (e.g., music, videos, books, or

games), and help in the completion of academic work (e.g., sending and receiving homework or online surveys). However, excessive SNS use may increase the level of FoMO. The feeling of fear of missing out important information or instant communication with others is often experienced. Greater fear and anxiety, especially state-FoMO as a specific context cognition, may in turn increase SNS use. Therefore, state-FoMO is closely related to feeling anxious and lost (i.e., one factor of smartphone addiction) as well as excessive SNS use. The node of SNS use also had an important role in the nodes of the network connection (i.e., closely associated with S2,S3 and state-FoMO, Figure 1), which indicated greater SNS use was associated with a higher level of FoMO.

Internet addiction and psychiatric symptoms may interact and precipitate each other (Beranuy et al., 2009). Chotpitayasunondh and Douglas (2016) reported that smartphone addiction may predict phubbing behavior and phubbee experiences, whereas the potential influence of emotional support from social media on phubbing behavior has been reported (Fang et al., 2020). The Dynamic Motivation Activation (DMA) model Wang et al., 2011; Wang & Tchernev, 2012) proposes that users' motivation may be changed by motivated media choices and use in real time, which further influences subsequent media choice and use. The reciprocal causality or mutual influence was useful in the present study. FoMO and excessive SNS usage may result in smartphone addiction and form a vicious ccle between FoMO, SNS use, and smartphone addiction.

The relationship between FoMO, SNS use, and smartphone addiction also was

Journal Pre-proof

explored using network analysis among a sample of Chinese university students. The network structure and the global strength of gender groups were compared by examining the invariance of network connectivity across gender. Consequently, the present study is the first to explore network connectivity between FoMO, SNS use, and smartphone addiction among a sample of Chinese university students, and verified the close and reciprocal relationship between aforementioned variables (i.e., Hypothesis 4).

In the domain-level network, inability to control craving (S1) and productivity loss (S4) had the strongest edge intensity. This indicated that university students spend large amounts of time on their smartphone and had an inability to control impulsive thoughts and behavior concerning their smartphone use, and triggering unavoidable negative outcomes (i.e., impairment of academic performance and working competency, and compromising interpersonal relationship). Huang et al. (2021) also reported that loss of control and excessive use were the core symptoms of problematic smartphone use utilizing network analysis among Grade 4 and Grade 8 students in China. In addition, feeling anxious and lost (S2) and state-FoMO (F2) were the core nodes. The S2 factor of smartphone addiction reflected the inability of adolescents to switch off their smartphone and was associated with intense emotional experience (anxiety, feeling lost, and total preoccupation) (Leung, 2008). The main characteristics of anxiety are fear and/or worry. Anxiety and fear are interrelated and often overlap. FoMO is considered as a type of social anxiety. State-FoMO especially stresses the importance of the special context, in which an

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internet-communication application (e.g., QQ and WeChat) is used (Wegmann et al., 2017). In addition, state-FoMO is also similar to state-anxiety, which has been found to be significantly and positively associated with excessive smartphone use (Shen et al., 2019). Some scholars have found that anxiety and depression may predict smartphone addiction (Kim & Koh, 2018; Chiu, 2014). On the contrary, smartphone addiction may also predict anxiety and depression (Hawi & Samaha, 2017; Geng et al., 2021). The present network analysis also demonstrated a reciprocal relationship between FoMO and smartphone addiction and SNS use, which is consistent with Billieux's (2012) pathway model.

In the item-level network, items s10 (*"You feel anxious if you have not checked for messages or switched on your mobile phone for some time"; the factor of feeling anxious and lost*) and s14 (*"You have used your mobile phone to talk to others when you were feeling lonely"; the factor of withdrawal/escape*) had a higher level of strength centrality in smartphone addiction. This indicated smartphone addiction was more closely associated with FoMO (i.e., anxiety check) and SNS use (i.e., SNS use for avoiding loneliness). Huang et al. (2021) also indicated that anxiety/restlessness and boredom had strong centrality which may be next only to central symptoms. The items x6 (*"I am continuously online in order not to miss out on anything"*) and x7 (*"It is important that I have a say about the latest issues in my online social networks [videos, images, posts, etc.]"*) were both in the state-FoMO dimension and had higher strength centrality in FoMO, which indicated FoMO, especially state-FoMO, more closely associated with smartphone addiction (i.e.,

Journal Pre-proof

continuously online) and SNS use (i.e., engage in online social networks). As Balta et al. (2020)' reported, state-FoMO was directly associated with problematic Instagram use, while trait-FoMO was indirectly associated with problematic Instagram use via state-FoMO. In addition, y8 (*"I would be sorry if SNSs shut down";* attitude to SNS activities) had the highest level of strength centrality in SNS use. This indicated SNS use was more closely associated with the fear of missing out on important events and being eager to communicate with others, and excessive/problematic SNS use was more likely lead to smartphone addiction. Smartphone addiction in turn may affect SNS use and FoMO, which further verified the reciprocal model of multivariables.

Although gender differences have been reported in posttraumatic stress disorder and social anxiety disorder symptoms (Cao et al., 2019; Heeren & McNally, 2018) using the network comparison test (NCT), the relationship in the present study between FoMO, SNS use, and smartphone addiction found no significant differences for gender, which means Hypothesis 5 was not supported. Mitchell and Hussain (2018) reported that no significant gender difference was found for problematic smartphone use, which is similar to the findings of the present study. However, some scholars have reported that there are significant gender differences concerning the motivations of social media use (Barker, 2009; Huang, Kumar, & Hu, 2018). Therefore, the relationship between FoMO, motivation of SNS use, and smartphone addiction requires further research to further delineate these relationships.

The present study has several limitations that should be considered. One of the

main limitations is the use of cross-sectional data, which might cannot determine causality between the variables. Therefore, a longitudinal network analysis should be conducted on the relationship between FoMO, SNS use, and smartphone addiction. Moreover, all data were collected by survey utilized self-report, which might result in well-known participant biases. More objective study methods and measurement tools (e.g., clinical diagnosis of smartphone addiction) should be used in future studies. Finally, convenience sampling was used to collect the data. In future research, a more representative sample should be considered. In addition, future research needs to examine the interaction of different levels of FoMO and different intensity of SNS use to smartphone addiction and the effect of different degrees of smartphone addiction to FoMO and SNS use. Moreover, gender as moderator impacting the relationship between FoMO and smartphone addiction and SNS use require further investigation. Potential bidirectional influences between smartphone addiction, SNS use and FOMO using cross-lagged/longitudinal network analysis should also be considered.

Conclusions

The relationship between FoMO, SNS use, and smartphone addiction was examined using network analysis. These results indicated that feeling anxious and lost, and state-FoMO were the core nodes in the relationship network between FoMO, SNS use, and smartphone addiction. A new perspective in the prevention of smartphone addiction is suggested by these findings. More specifically, practitioners developing interventions to overcome smartphone addiction should consider aspects

aimed at regulating and/or reducing excessive SNS use and controlling feelings of FOMO. In turn, prevention of smartphone addiction may also decrease excessive SNS use and relieve high levels of FoMO.

Availability of data and materials

The datasets supporting the conclusions of this article are available from the corresponding author upon reasonable request.

Competing interests

There are no financial or non-financial competing interests. None of the research staff received incentives for recruiting participants or for any other purpose directly associated with the study.

Consent for publication

Not applicable.

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Table 1 Sociodemographic characteristics

		N (100%)/ Mean±SD	FoMO Mean±SD	*t/F*	*p*	*Cohen's d/η²*	SAS Mean±SD	*t/F*	*p*	*Cohen's d/η²*	SNS use Mean±SD	*t/F*	*p*	*Cohen's d/η²*
Owned a smartphone	Yes	1143 (100%)	29.02±6.94				42.15±10.24				29.57±5.97			
Age		20.2±1.6												
Gender				1.78	0.075	0.106		0.97	0.335	0.057		2.79	0.005	0.166
	Male	502 (43.9%)	28.61±6.92				41.82±10.51				29.01±6.28			
	Female	641 (56.1%)	29.35±6.94				42.41±10.03				30.00±5.68			
Grade				2.62	0.05	0.007		1.81	0.143	0.005		4.63	0.003	0.012
	Freshmen	426 (37.3%)	29.76±6.91				42.19±10.38				29.41±5.93			
	Sophomore	149 (13%)	28.48±6.76				40.72±10.08				28.19±6.41			
	Junior	70 (6.1%)	28.46±8.26				40.91±11.53				29.16±7.03			
	Senior	498 (43.6%)	28.63±6.78				42.71±9.95				30.17±5.62			
Family structure				0.13	0.876	0.000		2.67	0.07	0.005		1.04	0.355	0.002
	parents	1011 (88.5%)	29.01±6.96				41.96±10.31				29.55±6.03			
	Single parent or stepparents	121 (10.6%)	29.03±6.71				43.98±9.69				29.93±5.46			
	Others (e.g., raised by grandparents or relatives)	11 (0.9%)	30.09±8.12				38.91±8.18				27.27±5.16			

Note: FoMO = Fear of missing out, SAS = Smartphone addiction, SNS use= Intensity of social networking site use; η^2 = effect size calculated by using eta-squared test

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Table 2 Correlation analysis of the study variables

	T-FoMO	S-FoMO	S1	S2	S3	S4	SNSI1	SNSI2	SNSI3	SNS use	FoMO	SAS
T-FoMO	1.00											
S-FoMO	0.40**	1.00										
log(BF_{10})	97.85											
S1	0.23**	0.26**	1.00									
log(BF_{10})	27.03	35.01										
S2	0.27**	0.45**	0.43**	1.00								
log(BF_{10})	39.52	127.99	112.10									
S3	0.26**	0.35**	0.34**	0.47**	1.00							
log(BF_{10})	35.21	70.93	66.29	140.45								
S4	0.22**	0.14**	0.54**	0.34**	0.30**	1.00						
log(BF_{10})	23.70	8.02	194.43	65.18	50.78							
SNSI1	0.04	0.14**	-0.01	0.07	0.05	0.02	1.00					
log(BF_{10})	-2.43	8.62	-3.28	-0.41	-2.09	-3.06						
SNSI2	0.07*	0.24**	0.17**	0.25**	0.21**	0.06*	0.28**	1.00				
log(BF_{10})	-0.84	29.06	13.40	33.79	21.63	-1.30	42.00					
SNSI3	0.21**	0.46**	0.21**	0.41**	0.35**	0.19**	0.25**	0.31**	1.00			
log(BF_{10})	22.20	128.62	21.21	102.64	71.26	18.45	31.88	55.94				
SNS use	0.18**	0.44**	0.19**	0.39**	0.32**	0.16**	0.60**	0.57**	0.89**	1.00		
log(BF_{10})	15.91	118.64	17.24	88.47	58.76	11.93	252.21	217.90	∞			
FoMO	0.79**	0.88**	0.29**	0.44**	0.37**	0.21**	0.12**	0.19**	0.41**	0.39**	1.00	
log(BF_{10})	∞	∞	46.46	121.34	79.03	21.44	4.46	17.86	103.01	89.61		
SAS	0.32**	0.42**	0.81**	0.80**	0.68**	0.66**	0.04	0.25**	0.40**	0.36**	0.45**	1.00
log(BF_{10})	59.72	109.24	∞	∞	347.95	316.44	-2.20	32.50	93.48	77.11	126.66	

Note: ** p<.01. T-FoMO = Trait-FoMO, S-FoMO = State-FoMO, S1= Inability to control craving, S2= Feeling anxious and lost, S3 = Withdrawal / escape, S4 = Productivity loss, SNSI1 =Numbers of SNS friends, SNSI2 = Time on SNS, SNSI3 = Attitude on SNS use, SNS use = intensity of Social networking site use, SAS = Smartphone addiction.

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Table 3 Centrality study variables relationship network

	Betweeness	Closeness	Strength
T-FoMO	-0.696	-0.824	-1.364
S-FoMO	0.603	0.809	1.087
S1	0.278	-0.145	0.356
S2	1.903	1.853	1.287
S3	-0.696	-0.460	-0.114
S4	-0.696	-0.961	-0.190
SNS use	-0.696	-0.271	-1.062

Note: T-FoMO = Trait-FoMO, S-FoMO = State-FoMO, S1= Inability to control craving, S2= Feeling anxious and lost, S3 = Withdrawal / escape, S4 = Productivity loss, SNS use = Intensity of social networking site use.

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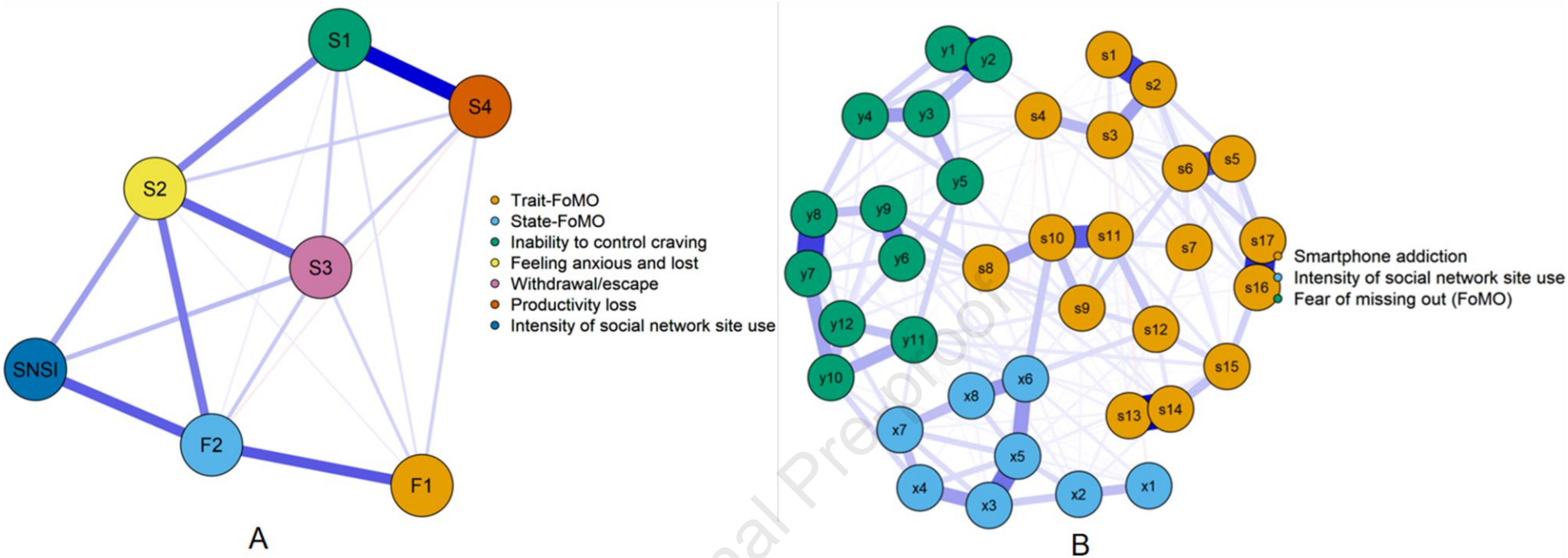

Figure 1. EBICglasso model based on the domain-level (A) and the item-level (B) network analysis according to the relationships between FoMO, smartphone addiction and SNSs among 1143 participants. Note: A: F1 = Trait-FoMO, F2 = State-FoMO, SNSI = Intensity of social networking site use, S1 = Inability to control craving, S2 = Feeling anxious and lost, S3 = Withdrawal / escape, S4 = Productivity loss; B: y1-y12 = Fear of missing out (FoMO), s1-s17 = Smartphone addiction, x1-x8 = Intensity of social networking site use.

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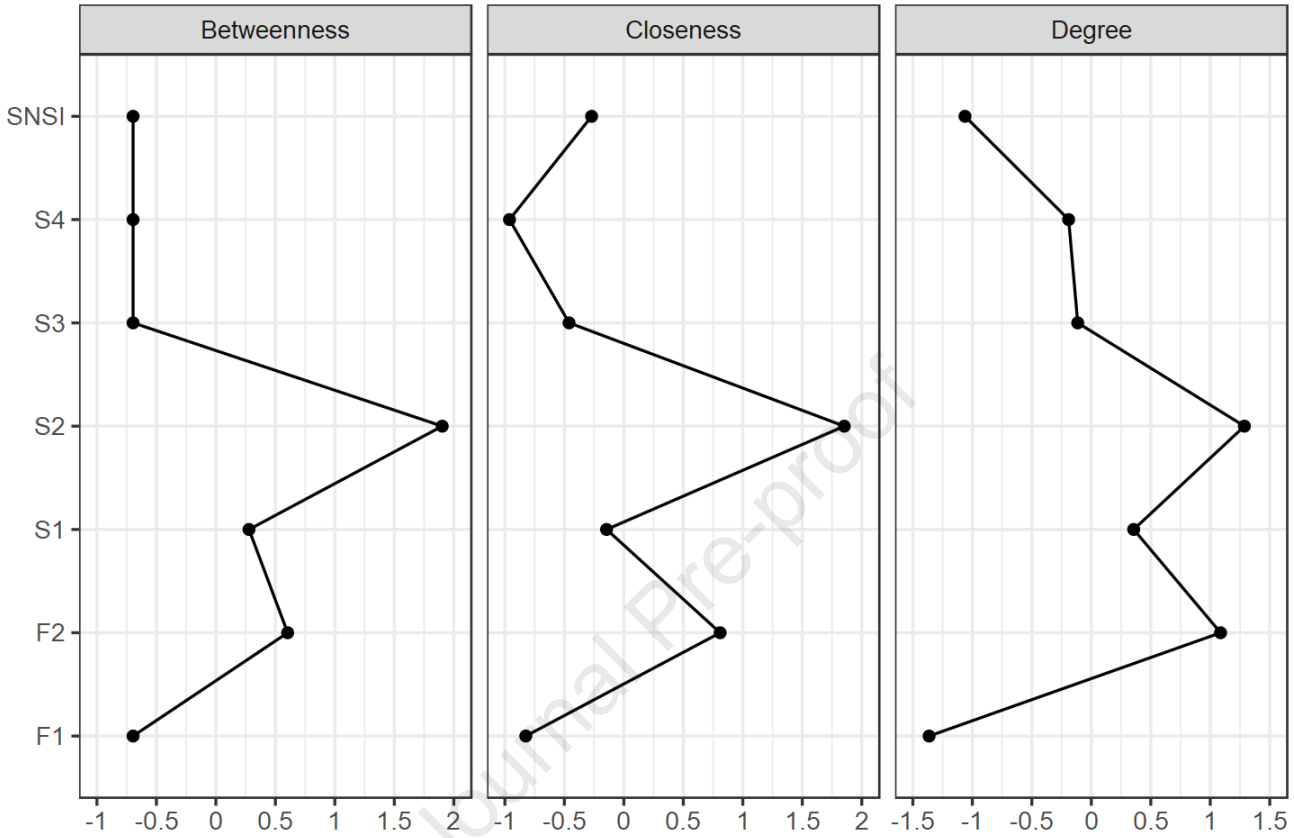

Figure 2. Centrality Plots for EBICglaaso network depicting the betweenness, closeness, and degree (strength) of each node (variable) among 1143 university students. Note: F1 = Trait-FoMO, F2 = State-FoMO, SNSI = Intensity of social networking site use, S1= Inability to control craving, S2= Feeling anxious and lost, S3 = Withdrawal / escape, S4 = Productivity loss.

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Highlights

- Network analysis has rarely been used to examine smartphone addiction
- Inability to control craving and productivity loss had the closest edge intensity
- Feeling anxious and lost was the strongest central node in the domain-level network.
- The relationship between FoMO, SNS use, and smartphone addiction was close in the item-level network.
- There were no significant gender differences in the network structure and the global edge strength.

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