

# Age Differences in the Associations Between Interpersonal Relationships and Short-Form Video Addiction Symptoms: A Network Analysis

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**Purpose:** A considerable body of evidence indicated that interpersonal relationships were significantly associated with short-form video addiction (SFVA) among adolescents, but how they are related on a symptom level at different ages remains unclear. This study aimed to explore the central symptoms of SFVA and distinct associations between three primary interpersonal relationships (ie, teacher–student relationships, parent–child relationships, peer relationships) and SFVA symptoms in early and middle adolescence.

**Participants and Methods:** After completing scales of SFVA, teacher–student relationship, parent–child relationship and peer relationship in 2022, a sample of 1579 fourth-grade students (age range: 10–12;  $M_{\text{age}} = 10.91$ ,  $SD = 0.48$ ; 38.6% females) and 2229 eighth-grade students (age range: 13–15;  $M_{\text{age}} = 14.82$ ,  $SD = 0.36$ ; 44.5% females) who were at high risk of SFVA were included in this study. A network analysis approach was conducted to analyze the data.

**Results:** SFVA3 *hard to control* and SFVA2 *increasing time for satisfaction* were the most central symptoms of SFVA in both early and middle adolescence. Among interpersonal relationships, teacher–student relationships and peer relationships were the most influential bridge nodes that exerted the largest impact on SFVA in early and middle adolescence, respectively. Comparison of the networks indicated no significant differences in overall network structures, global strength and most edge connections between early and middle adolescence.

**Conclusion:** These findings uncover the interconnections between heterogeneous SFVA symptoms and underscore the unique importance of teacher–student relationships and peer relationships on SFVA in different stages of adolescence, which can be harnessed in the design of future preventive interventions.

**Keywords:** short-form video addiction, interpersonal relationships, network analysis, age differences

## Introduction

In recent years, short-form video apps have attracted a large number of audiences due to their concise format (usually a few seconds to a few minutes), engaging content, personalized recommendations, and rapid dissemination.<sup>1,2</sup> With minimal interaction costs, users can receive rich informational stimuli and experience high levels of immersion. The personalized content recommendation algorithms further reinforce their usage, making short-form video consumption increasingly habitual and difficult to control.<sup>3</sup> This raises widespread concerns about its potential negative effects on adolescents, especially about short-form video addiction (SFVA). According to Wang and Lei,<sup>4</sup> SFVA can be defined as individuals' inability to control their use of short-form video apps regardless of the negative psychological and social consequences. In China, over 50.0% of minors regularly watch short-form videos online, and the proportion is still increasing.<sup>5</sup> Adolescents, given their immature biological and psychosocial functioning,<sup>6,7</sup> are extremely susceptible to SFVA. Resembling other types of Internet addiction, SFVA is detrimental to adolescents' physical and mental health in

many ways, such as reduced physical activity, academic failures, interpersonal impairment, and risk of depression and anxiety.<sup>8–10</sup> Given the prevalence and potential negative consequences of SFVA, it is important to identify its underlying mechanisms. Relationships with parents, teachers, and peers play significant roles in adolescents' social lives, and previous studies have suggested that they are all related to various technology addictions among adolescents, including SFVA.<sup>11–13</sup> However, conventional studies mainly regard SFVA as a single variable and only focused on the influence of one or two types of interpersonal relationships, obscuring the interconnections between heterogeneous SFVA symptoms, as well as between SFVA symptoms and the complex system of interpersonal relationships. Additionally, it is also unclear whether these associations change across different developmental stages. To fill these gaps, this study adopted a network perspective to explore age differences in the central symptoms of SFVA and associations between interpersonal relationships (ie, parent–child relationships, teacher–student relationships, peer relationships) and SFVA symptoms from early to middle adolescence.

## Associations Between Interpersonal Relationships and Short-Form Video Addiction

According to the Interaction of Person-Affect-Cognition-Execution (I-PACE) Model of specific Internet-use disorders,<sup>14</sup> among the predisposing factors of Internet addiction, social cognitions are primarily linked with excessive use of applications with communication features (eg, short-form video apps). Individuals who perceive lack of social support, feelings of isolation, and loneliness may hold biased expectancies on the Internet, turn to the Internet to compensate for their unmet needs in real life and thus tend to develop addictive online behaviors. In line with this, it has been found that offline social support and relatedness needs were negatively related with SFVA among adolescents.<sup>15</sup> During adolescence, family, school, and peers are immediate social environments and essential support contexts related to individuals' social adjustment and functioning, where relationships with parents, teachers and peers are core components.<sup>16</sup> Hence, these three types of interpersonal relationships may be significantly associated with SFVA.

As short-form video is an emerging type of online media usage, to date, there have been relatively few studies examining the link between interpersonal relationships and SFVA in adolescence. A study conducted on adolescents aged 12 to 18 found that compared to non-users and moderate users, addictive users of TikTok exhibited higher levels of loneliness, worse parental relationships and more bullying victimization.<sup>17</sup> Another study on students aged 11 to 18 found that among the multiple social-environmental factors, parent–child relationships and classmate relationships were negatively correlated with SFVA, but the effect of teacher–student relationships was not significant.<sup>12</sup> This may be due to the fact that the sample in this study included only middle and high school students. Notwithstanding this, the associations between interpersonal relationships and Internet addiction have been extensively investigated, and such studies either examined the correlations between certain types of interpersonal relationships and Internet addiction or explored the mechanism of Internet addiction by treating certain types of interpersonal relationships as mediators or moderators. For example, parent–child relationships,<sup>18</sup> teacher–student relationships<sup>11</sup> and peer relationships<sup>19</sup> were all found to be negatively associated with adolescent Internet addiction, positive teacher–student relationships could ameliorate the adverse impact of peer victimization on Internet addiction among adolescents,<sup>20</sup> and peer alienation played a mediating role in the relationship between parental attachment and problematic Facebook use.<sup>21</sup> However, there exist some potential gaps in prior studies. First, the analyses were always based on the total score of SFVA, rather than the internal components, which obscures the heterogeneity and intricate connections of different symptoms.<sup>22</sup> In addition, seldom did researchers simultaneously investigate all three types of interpersonal relationships that cover all micro-systems around adolescents, thereby reducing the ecological validity of the research. Except for these, most studies included participants of a wide age range,<sup>13,18,19</sup> but did not divide them into different age groups to obtain more comprehensive results.

## Age Differences Between Early and Middle Adolescence

Adolescence is the life phase stretching between childhood and adulthood, and its definition has long posed a conundrum.<sup>23</sup> The most commonly used chronological definition of adolescence encompasses the ages of 10–18 years,<sup>24,25</sup> during which 10–12 years are categorized as early adolescence, and 13–15 years are categorized as middle adolescence.<sup>26,27</sup> Characterized by the onset of accelerated physical and sexual maturation in early adolescence and a psychosocial

orientation accentuating social independence in middle adolescence, these two stages show developmental differences in many aspects.

Nowadays, driven by the unprecedented social forces (ie, digital media), age differences in adolescents' Internet addiction are becoming a critical research direction.<sup>28</sup> Research conducted in various countries has consistently shown that early adolescence represents a crucial point for the onset of Internet addiction, and there is a rapid increase in the prevalence of Internet addiction from early to middle adolescence.<sup>29–33</sup> From early to middle adolescence, students have easier access to smartphones, and tend to have poorer impulse control.<sup>24</sup> Longitudinal studies have also proven this trend. In a representative study among Taiwanese adolescents, Hsieh et al<sup>34</sup> found a linear increase in Internet addiction from fourth to eighth grade. Similarly, a quadratic growth curve was fit for the development of problematic smartphone use among adolescents aged 10–18 years, in which a significant acceleration in the growth rate was observed from early to middle adolescence.<sup>35</sup> Unlike Internet addiction, studies examining age differences in SFVA are scarce. Compared to general Internet apps, short-form video apps rely on more accurate and efficient recommendation algorithms, which require shorter durations on each stimulus but continuous engagement overall.<sup>1,36</sup> Hence, it will be meaningful to interpret developmental changes of SFVA during adolescence for timely prevention and intervention.

On the other hand, affected by common age-graded life experiences, the salience of specific relationships varies across childhood and adolescence.<sup>37</sup> As the basis of building and maintaining relationships with others, attachment to parents has a fundamental and lifelong impact on children's development.<sup>38</sup> Afterward, when children enter school, teachers, as authoritative figures beyond parents, progressively play an important role in their lives.<sup>39</sup> When the advent of puberty brings profound changes to adolescents, it also marks the more equal and parallel relationship with peers taking precedence in their social lives.<sup>40</sup> Especially since middle adolescence, the influence of peer relationships even surpasses that of parent-child and teacher-student relationships.<sup>41,42</sup> In this regard, how SFVA symptoms relate to different relational domains might exhibit disparate developmental patterns across adolescence. Specifically, when considering age differences, identifying the most salient interpersonal relationships at different age stages is crucial because previous studies have shown that correspondingly targeted intervention can effectively reduce problematic behaviors such as smoking and alcohol abuse among adolescents.<sup>43</sup> However, in terms of interpersonal relationships, existing studies mainly focused on the underlying mechanisms of SFVA, rather than their relative importance.<sup>4,44</sup> To our knowledge, only one study has examined age differences in the impact of parent-child and peer relationships on Facebook addiction and found that parent-child relationships were more influential for adolescents aged 12 to 13, while peers were of greater significance for adolescents aged 14 to 17.<sup>45</sup> Therefore, in light of a growing demand in operable mental health care, it is necessary to investigate whether and how the three interpersonal relationships are associated with SFVA symptoms in early and middle adolescence.

## Network Analysis

Traditional psychological research conceptualized symptoms of a mental disorder as manifestations of latent constructs and described its severity with the total scores of standardized instruments.<sup>46</sup> In recent years, researchers have pointed out that symptoms of mental disorders are interdependent and cannot be attributed to a common cause.<sup>47,48</sup> Building on this, the network theory of mental disorders was proposed, which posited that mental disorders arise from causal interactions between symptoms in a network and emerge when a tightly connected set of symptoms is activated and mutually reinforce.<sup>49</sup>

To portray the complex interplay of psychological components, network analysis is a novel method for estimating and visualizing symptoms and their connections.<sup>50</sup> A typical network consists of nodes representing observed variables and are connected by edges representing their statistical relationships. By emphasizing the interrelations between symptoms, network analysis may provide nuanced insights into the nature and optimal treatment of psychopathology. Firstly, according to three major centrality indices (strength, betweenness, closeness), network analysis can determine central symptoms that not only contribute to figuring out the underlying mechanisms of mental disorders but also provide focal points for interventions.<sup>51,52</sup> Secondly, network analysis allows examination of connections of components within and across communities of disorders or related factors, which is particularly useful for identifying the bridge components that

connect these communities.<sup>53,54</sup> Lastly, network analysis enables researchers to statistically compare networks of different subgroups in terms of network structure, global strength and edge strength.<sup>55</sup>

Currently, network analysis has been widely applied to research on various problematic online behaviors, including smartphone addiction,<sup>56,57</sup> social media addiction,<sup>58,59</sup> and Internet addiction.<sup>60–62</sup> Of the existing studies, only a few studies have focused on the age differences in the networks of problematic online behaviors. For example, in a study aimed to identify core symptoms of problematic Internet use across the entire adolescence, “increasing time for satisfaction” and “empty life” were found to be the central symptoms in early adolescence, with “less sleep”, “failure to stop”, and “feeling depressed” in middle adolescence, and “feeling depressed” in late adolescence.<sup>25</sup> In contrast, a larger number of studies have attempted to determine key factors that influence problematic online behaviors. For example, among 3rd to 10th grade students, when considering multiple individual and environmental factors that might be related to problematic smartphone use, factors concerning peers (ie, peer attitudes toward smartphone use, peer pressure for smartphone use, and friendship quality) were more influential than factors from other microsystems.<sup>63</sup> However, so far, little attention has been paid to SFVA and its related factors. To date, only one study has utilized network analysis to explore the longitudinal relationships between SFVA and depressive symptoms in a sample of college students aged 17–29 years.<sup>64</sup> Hence, to fully understand this emerging type of technology addiction, this study aimed to use a network analysis approach to explicitly illuminate the developmental changes of SFVA symptoms and their associations with interpersonal relationships.

## Current Study

Although some studies have indicated that interpersonal relationships were associated with SFVA among adolescents, a more detailed association with SFVA symptoms and age differences between early and middle adolescence remains unclear. To address these gaps, the current exploratory study adopted a network analysis approach with the following objectives: firstly, estimating networks of SFVA symptoms to depict their interconnections and unveil the central symptoms of SFVA; secondly, constructing networks of SFVA symptoms and parent–child relationships, teacher–student relationships, peer relationships to demonstrate their associations and identify the bridge nodes connecting these two communities; lastly, comparing the above findings between early and middle adolescence to uncover potential age differences, particularly to figure out whether they differ in the relative impact of parent–child relationships, teacher–student relationships and peer relationships.

## Material and Methods

### Participants and Procedure

Data of the current study were from a regional education quality assessment program designed to assess the mental health of adolescents in China. Similar to the Program for International Student Assessment (PISA) of the Organization for Economic Co-operation and Development (OECD), and the Trends in International Mathematics and Science Study (TIMSS) of the International Association for the Evaluation of Educational Achievement (IEA), this program selected fourth and eighth-grade students to represent primary school and middle school adolescents in consideration of the representativeness and cost-effectiveness.

Ethics approval was obtained from the Ethics Committee of the Collaborative Innovation Center of Assessment for Basic Education Quality, Beijing Normal University (2022–58). Before data collection, permission from school principals and informed assent from participants and their parents were obtained. All participants were informed that the data would be only used for scientific research. Using cluster sampling, fourth and eighth-grade students from 359 primary schools and 177 middle schools in 11 districts were selected in 2022. Initially, a total of 28,562 fourth-grade students and 15,916 eighth-grade students participated in the program. To align with the objectives of this study, students who had never used short-form video apps were excluded (47.6% fourth-grade students; 26.4% eighth-grade students). After selecting those at high risk of SFVA (mean score  $\geq 3$ ), 1579 fourth-grade students (age range: 10–12;  $M_{\text{age}} = 10.91$ ,  $SD = 0.48$ ; 38.6% females) and 2229 eighth-grade students (age range: 13–15;  $M_{\text{age}} = 14.82$ ,  $SD = 0.36$ ; 44.5% females) were included in the final analysis, representing early adolescence and middle adolescence, respectively. Among them, 19.4%

of fourth-graders and 21.8% of eighth-graders were the only child in the family; 11.7% of fourth-graders and 11.9% of eighth-graders were from a single-parent family.

## Measures

### Short-Form Video Addiction

The 8-item Short-form Video Addiction Scale,<sup>4</sup> derived from the Internet Addiction Scale,<sup>65</sup> was used to assess adolescents' SFVA. After replacing "Internet" with "short-form videos" in each item, eight symptoms of SFVA stemming from Internet addiction were determined: *feeling occupied, increasing time for satisfaction, hard to control, withdrawal, longer than intended, interpersonal loss, lying to conceal, escaping*.<sup>66,67</sup> Table 1 shows a detailed description of the items and the corresponding SFVA symptoms. Participants rated the items on a 5-point scale from 1 (strongly disagree) to 5 (strongly agree). Mean scores of all items were calculated, with higher scores indicating higher levels of SFVA. In this study, Cronbach's alpha was 0.732 for early adolescence and 0.743 for middle adolescence.

### Parent–Child Relationships

The Chinese version of the Network of Relationships Inventories<sup>68,69</sup> was used to assess parent–child relationships,<sup>70</sup> in which 11 items of good qualities were retained due to the limited length of the questionnaire (eg, "How much do your parents help you when you need to get something done?" "How often do you and your parents argue with each other?"). Participants rated the items on a 4-point Likert scale ranging from 1 (never) to 4 (always). After reversing the scores of 4 items, mean scores of all items were calculated, with higher scores indicating better relationships with parents. In this study, Cronbach's alpha was 0.811 for early adolescence and 0.851 for middle adolescence.

### Teacher–Student Relationships

Five items from PISA 2012<sup>71</sup> were adapted to assess teacher–student relationships, which also showed good reliability and validity among Chinese adolescents in previous research.<sup>72–74</sup> Based on the educational context in China, the questionnaire was designed to capture whether teachers show respect, fairness, and trust towards students during their interactions (eg, "I get along well with most of my teachers" "Most teachers are very concerned about my physical and mental well-being"). Participants rated the items on a 5-point scale from 1 (strongly disagree) to 5 (strongly agree). Mean scores of all items were calculated, with higher scores indicating better relationships with teachers. In this study, Cronbach's alpha was 0.907 for early adolescence and 0.925 for middle adolescence.

**Table 1** Description of SFVA Symptoms

	Item	Abbreviation
SFVA1	I feel preoccupied with short-form video apps (think about previous on-line activity or anticipate next on-line session).	Feeling occupied
SFVA2	I feel the need to use short-form video apps with increasing amounts of time to achieve satisfaction.	Increasing time for satisfaction
SFVA3	I repeatedly made unsuccessful efforts to control, cut back, or stop using short-form video apps.	Hard to control
SFVA4	I feel restless, moody, depressed, or irritable when attempting to cut down or stop using short-form video apps.	Withdrawal
SFVA5	I use short-form video apps longer than originally intended.	Longer than intended
SFVA6	I jeopardized or risked the deterioration of significant relationships, academic performance in real life because of short-form video apps.	Interpersonal loss
SFVA7	I lied to family members, friends, or others to conceal the time or money spent on short-form video apps.	Lying to conceal
SFVA8	I use short-form video apps as a way of escaping from problems or of relieving a dysphoric mood (eg, feelings of helplessness, guilt, anxiety, depression).	Escaping



## Peer Relationships

The Children's Loneliness Scale<sup>75</sup> was adapted to assess students' peer relationships. A 10-item scale was formed with 7 items of good qualities from the CLS based on the results of the pilot study and 3 additional questions on relationships with classmates (eg, "I feel lonely in my class" "My classmates often bully me").<sup>70</sup> Participants rated the items on a 4-point Likert scale ranging from 1 (never) to 4 (always). After reversing the scores of 5 items, mean scores of all items were calculated, with higher scores indicating better relationships with peers. In this study, Cronbach's alpha was 0.772 for early adolescence and 0.837 for middle adolescence.

## Data Analysis

Descriptive statistics were performed in SPSS (Version 26.0), and network analysis was performed in R (Version 4.2.1) in the current study. In total, two types of networks were constructed: one (SFVA networks) comprised solely of SFVA symptoms, and the other (SFVA-IR networks) included parent-child relationships, teacher-student relationships and peer relationships as well. First, the Gaussian graphical model (GGM), using the graphical LASSO in combination with the EBIC model was conducted to estimate the networks, where the partial correlation coefficients provided by the model quantify edges between two nodes in the networks. Then,<sup>76</sup> was used to visualize the networks and compute traditional centrality indices (strength, betweenness, closeness) to determine the central symptoms in the SFVA networks.<sup>77</sup> For the SFVA-IR networks, bridge strength centrality (the sum of a node's connectivity with other communities) computed by *networktools* package<sup>78</sup> was better suited to identify the bridge nodes connecting interpersonal relationships and the SFVA communities.<sup>79</sup> Additionally, it is recommended to evaluate the accuracy and stability of the networks using *bootnet* package (Epskamp et al, 2018).<sup>80</sup> Specifically, the accuracy was estimated by bootstrapping the 95% confidence intervals (CIs) of the edge weights, the correlation stability coefficient (CS coefficient) of the centrality indices representing the maximum proportion of cases that can be dropped was calculated, and the bootstrapped differences of two edge-weights or centralities were tested to see if they differ from each other.<sup>80</sup> After completing the above procedures within early and middle adolescence separately, the *NetworkComparisonTest* package was used to assess differences in the SFVA and the SFVA-IR networks between these two age groups, in which network invariance test was evaluated by the differences in the strength of the maximum edge of the network, the global strength invariance test was evaluated by the differences in the sum of the edge strengths, and the edge invariance test was evaluated by the differences between specific edges in the networks.<sup>55</sup>

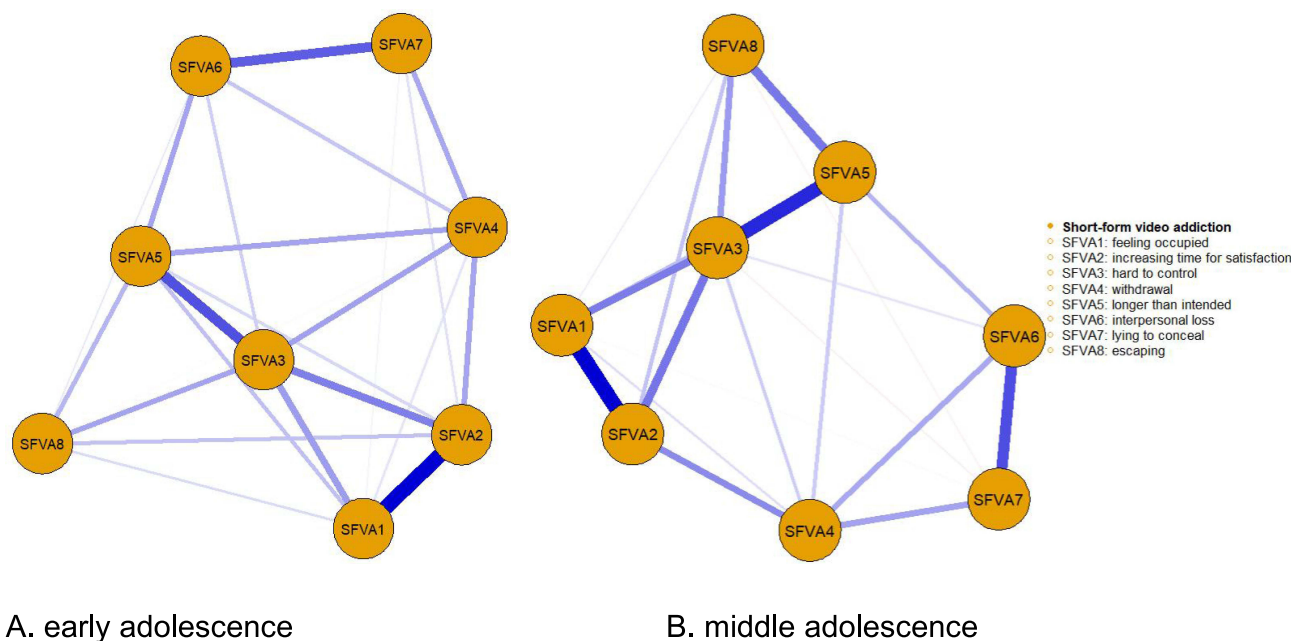
## Results

### SFVA Networks

Figure 1 shows the network structures of SFVA symptoms. In both early and middle adolescence, SFVA1 *feeling occupied* and SFVA2 *increasing time for satisfaction* had the strongest edge weight among all the nodes. In addition, SFVA3 *hard to control* and SFVA5 *longer than intended*, SFVA6 *interpersonal loss* and SFVA7 *lying to conceal* were also both strongly correlated.

Figure 2 shows centrality indices of SFVA symptoms. In early adolescence, SFVA3 *hard to control* and SFVA2 *increasing time for satisfaction* had the highest strength centrality, SFVA5 *longer than intended* had the highest betweenness centrality, and SFVA3 *hard to control* had the highest closeness centrality. In middle adolescence, SFVA3 *hard to control* and SFVA2 *increasing time for satisfaction* had the highest strength centrality, SFVA2 *increasing time for satisfaction* had the highest betweenness centrality, and SFVA3 *hard to control* had the highest closeness centrality. Therefore, the most central symptoms of SFVA in both adolescent stages were SFVA3 *hard to control* and SFVA2 *increasing time for satisfaction*.

The results of network accuracy and stability can be found in [Supplemental Materials](#). Edge weights bootstrapping ([Supplementary Figure 1](#)) indicated moderate accuracy for both networks, with considerable overlap between the 95% CIs of the edge weights. The CS coefficients ([Supplementary Figure 2](#)) indicated excellent stability of strength (0.75 in early and middle adolescence), closeness (0.75 in early and middle adolescence) and betweenness in middle adolescence



**Figure 1** Network structures of SFVA symptoms in (A) early adolescence ( $n = 1579$ ) and (B) middle adolescence ( $n = 2229$ ).

**Notes:** The thickness of edges reflects the partial correlation coefficients between nodes. Blue edges represent positive correlations, and red edges represent negative correlations. See Table 1 for detailed descriptions of SFVA symptoms.

(0.44), but unsatisfactory stability of betweenness in early adolescence (0.13). Results of edge difference test in both networks can be seen in [Supplementary Figure 3](#).

[Supplementary Figure 4](#) depicted the networks of the two subgroups in a “circle” layout, facilitating for comparing networks visually. The network comparison test suggested that there were no statistically significant differences between the two networks concerning overall network structure ( $p = 0.124$ ) and global strength ( $p = 0.741$ ). Furthermore, edge invariance test revealed that several edges were significantly different between the two networks. That is, the edges between SFVA2 *increasing time for satisfaction* and SFVA5 *longer than intended* ( $p = 0.038$ ) as well as between SFVA6 *interpersonal loss* and SFVA8 *escaping* ( $p = 0.045$ ) were stronger in early adolescence, whereas the edge between SFVA5 *longer than intended* and SFVA8 *escaping* ( $p = 0.006$ ) was stronger in middle adolescence.

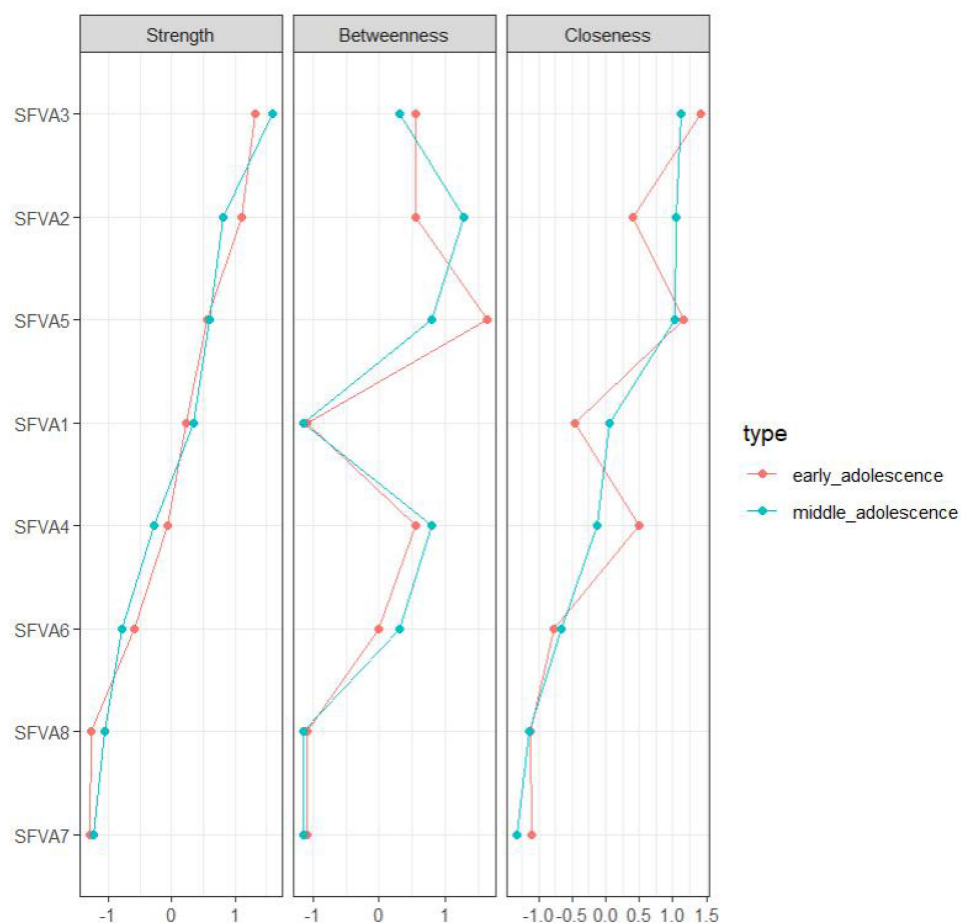
## SFVA and Interpersonal Relationships Networks

[Figure 3](#) shows the network structures of interpersonal relationships and SFVA symptoms. Differences were observed among the connections between interpersonal relationships and the SFVA community. In early adolescence, teacher–student relationships were strongly correlated with SFVA6 *interpersonal loss*, and peer relationships were strongly correlated with SFVA7 *lying to conceal*. In middle adolescence, peer relationships were strongly correlated with SFVA4 *withdrawal* and SFVA6 *interpersonal loss*.

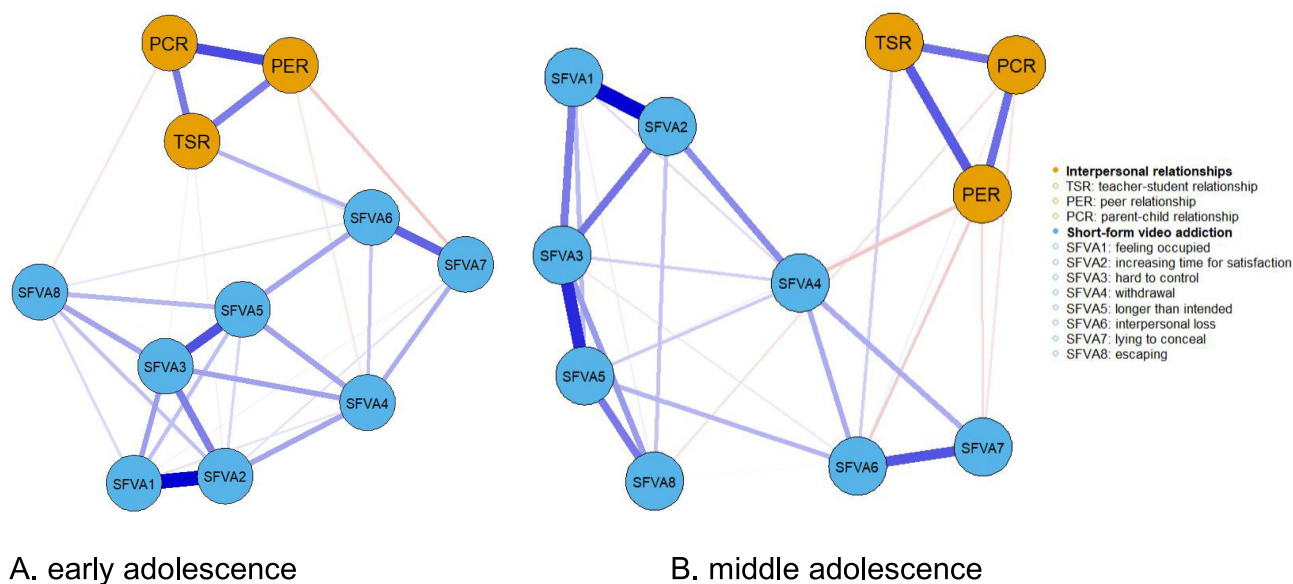
The result of bridge strength centrality (see [Figure 4](#)) also revealed age differences. In early adolescence, teacher–student relationships and SFVA6 *interpersonal loss* among the two communities showed the highest bridge strength. In middle adolescence, peer relationships and SFVA4 *withdrawal* among the two communities showed the highest bridge strength.

The results of network accuracy and stability can be found in [Supplemental Materials](#). Edge weights bootstrapping ([Supplementary Figure 5](#)) indicated moderate accuracy of both networks, with considerable overlap between the 95% CIs of the edge weights. The CS coefficients ([Supplementary Figure 6](#)) indicated excellent stability of bridge strength (0.67 in early and middle adolescence). Results of edge difference test in both networks can be seen in [Supplementary Figure 7](#).

[Supplementary Figure 8](#) depicted the networks of the two subgroups in a “circle” layout, facilitating for comparing networks visually. The network comparison test suggested that there were no statistically significant differences between

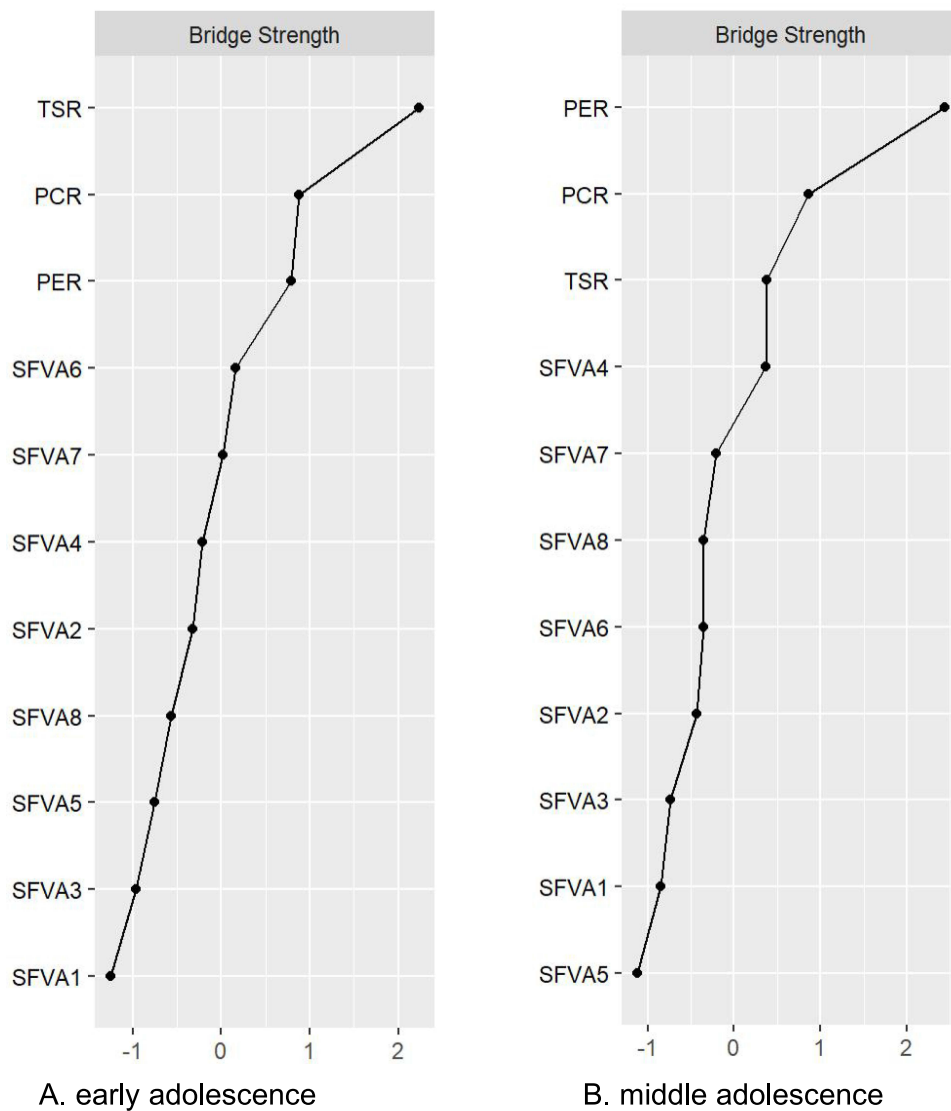


**Figure 2** Centrality of the nodes in the SFVA networks in early and middle adolescence (z-score).



**Figure 3** Network structures of interpersonal relationships and SFVA symptoms in (A) early adolescence (n = 1579) and (B) middle adolescence (n = 2229). **Notes:** The thickness of edges reflects the partial correlation coefficients between nodes. Blue edges represent positive correlations, and red edges represent negative correlations. See Table 1 for detailed descriptions of SFVA symptoms.





**Figure 4** Bridge strength centrality of the nodes in the SFVA-IR networks in (A) early and (B) middle adolescence (z-score).

the two networks concerning overall network structure ( $p = 0.119$ ) and global strength ( $p = 0.835$ ). Furthermore, edge invariance test revealed that only one edge connecting interpersonal relationships and the SFVA community was significantly different between the two networks. That is, the edge between peer relationships and SFVA6 *interpersonal loss* ( $p = 0.019$ ) was stronger in middle adolescence.

## Discussion

Driven by an emerging trend in interpretations of observable symptoms and symptom relationships in psychopathology, the present study applied network analysis to examine differences in the associations between parent–child relationships, teacher–student relationships, peer relationships and SFVA symptoms from early to middle adolescence. Albeit with no significant differences in overall network structures, global strength and most edge connections between early and middle adolescence, this study identified SFVA3 *hard to control* and SFVA2 *increasing time for satisfaction* as the most central symptoms of SFVA and underscored the unique impact of teacher–student relationships in early adolescence and peer relationships in middle adolescence on SFVA, which to some extent, are enlightening for understanding symptoms and influencing factors of SFVA and revealing age-specific differences.

In the SFVA networks, SFVA3 *hard to control* and SFVA2 *increasing time for satisfaction* had the highest strength centrality in both early and middle adolescence, which is consistent with the “loss of control” and “excessive use” highlighted in the criteria for Internet addiction.<sup>81–83</sup> Similarly, a network analysis of core symptoms of problematic Internet use in early, middle, and late adolescence found that “increasing time for satisfaction” showed high strength centrality in all three stages.<sup>25</sup> Additionally, the authors conducted another study in a larger sample of Chinese adolescents and also found that “reluctant to stop” and “increasing time for satisfaction” were particularly central symptoms of problematic Internet use during adolescence.<sup>84</sup> The prominence of these two symptoms, to some extent, corresponds to the features of short-form video apps. As technical factors that positively promote one’s attachment to short-form video apps, personalization (ie, customized content for users on the basis of the analysis of their preferences) and entertainment (eg, various special effect filters, fun stickers, and video editing tools) features of these apps have powerful magnetizing effect on adolescents to heavily use them, and eventually be addicted.<sup>85</sup> Meanwhile, adolescents often experience a cognitive state of “flow” while using short-form video apps, which can increase satisfaction and future usage intentions,<sup>86</sup> and is also a key factor in problematic TikTok use.<sup>87</sup> Continuously exposed to and reinforced by the new and timely recommended content of interest, it is difficult for adolescents to disengage from the “flow” experience and control their use of short-form video apps.<sup>88</sup> Accordingly, active mediation of parents and teachers on controlling adolescents’ time spent in short-form video apps is imperative.

In this study, more pronounced age differences were observed in the connections between interpersonal relationships and the SFVA community. Overall, among interpersonal relationships, teacher–student relationships and peer relationships exerted the largest impact in early and middle adolescence, respectively, as indicated by the bridge centrality. In China, students in early and middle adolescence spend approximately 60%–80% of waking hours at school, where they are predominantly accompanied and supported by teachers and peers. In early adolescence, it is undeniable that teachers’ relationships with their students share significant similarities with the parent–child relationships.<sup>89</sup> Teachers may serve as temporary attachment figures and function as secure bases that students can turn to for comfort, providing them with a haven to comfortably explore and interact with the social world.<sup>90,91</sup> Moreover, students’ academic achievements are highly valued in China’s educational context. On this occasion, teachers, as the main evaluators of students’ competencies and academic development,<sup>92</sup> will wield significant influence on their social adjustment, especially on externalizing and internalizing behavior.<sup>89</sup> Nevertheless, in middle adolescence, the influence of teachers may get weakened because of adolescents’ exposure to multiple teachers across school years and the escalating importance of peers.<sup>93</sup> During this stage, adolescents typically share a desire for emancipation and seek more autonomy from their families and schools. Consequently, peer relationships become more salient as adolescents navigate their social environments and form connections with their peers.

As for specific edges, there was a highest positive correlation between teacher–student relationships and SFVA6 *interpersonal loss* (“I jeopardized or risked the deterioration of significant relationships, academic performance in real life because of short-form video apps”) in early adolescence and a highest negative correlation between peer relationships and SFVA4 *withdrawal* (“I feel restless, moody, depressed, or irritable when attempting to cut down or stop using short-form video apps”) in middle adolescence. As mentioned above, when primary students feel warmth and support from teachers, they will also be more sensitive to their academic performance, leading to a tendency to attribute their academic decline more to the use of short-form video apps, especially for those at high risk of SFVA. On the other hand, according to the compensatory model of Internet use,<sup>94</sup> SFVA can be a way to alleviate negative feelings and compensate for psychosocial problems (eg, depression, loneliness) when confronted with negative life situations. Thus, in middle adolescence featuring a higher investment in peer groups, students with poor peer relationships in real life may turn to short-form video apps to fulfill their unsatisfied needs missing from others around and regulate negative affect,<sup>95</sup> but dependency on these apps requires growing amount of engagement to gain enough satisfaction, so they will easily get irritable when disconnected.<sup>96</sup>

Interestingly, in this study, parent–child relationships did not emerge as the most influential bridge node either in early adolescence or in middle adolescence and showed relatively weak connections with SFVA symptoms. Nonetheless, subtle changes in the associations between parent–child relationships and SFVA symptoms were observed as age increased. That is, in addition to the edge between parent–child relationships and SFVA8 *escaping* in early adolescence, SFVA6 *interpersonal loss* and SFVA7 *lying to conceal* were also significantly correlated with parent–child relationships in middle adolescence, suggesting a more profound and broader impact. One possible explanation for these findings is

that parent–child relationships, serving as the foundation that shapes patterns of interaction with others, may function as a more distal factor for school-aged adolescents. Thus, they may indirectly influence SFVA symptoms through their impact on teacher–student relationships or peer relationships,<sup>16</sup> which was indicated by the strong intercorrelations between these interpersonal relationships. Another possible explanation is that homes are where adolescents primarily use short-form video apps. Within domestic environments, adolescents’ digital media use may be more directly influenced by factors such as parental attitudes, parent–child communication, and the norms established by family members on electronic device usage, so that the effect of parent–child relationships within a family context is not so direct, rapid and clear as expected. Taken together, when formulating practical strategies to prevent SFVA among adolescents, priority should be given to interactions with teachers in early adolescence and enhancement of peer relationships quality in middle adolescence.

Although some valuable findings were obtained in this study, several limitations still need to be considered. First, despite highlighting age differences, all analyses were based on cross-sectional data. Nowadays, significant progress has been made in network analysis methodology for longitudinal data.<sup>97,98</sup> To further elucidate the developmental changes of associations between interpersonal relationships and SFVA symptoms during adolescence, future research may benefit from employing longitudinal analyses such as dynamic networks.<sup>99</sup> Second, the results of network analysis would be affected by the selection of the sample, but our study only included a limited sample of adolescents from two provinces of China, as indicated by the relatively low stability of betweenness centrality in the SFVA networks.<sup>80</sup> Thus, a more sizable and representative sample may be preferable for future research. Third, the measurement and assessment of SFVA symptoms in this study were both based on Internet addiction criteria. However, unique features of SFVA are quite essential for understanding its symptomatology,<sup>100</sup> which means future research using more reliable and valid assessments tailored to SFVA are warranted.

## Conclusion

Based on the I-PACE model of specific Internet-use disorders and network theory of mental disorders, the current study applied network analysis to investigate associations between interpersonal relationships (ie, teacher–student relationships, parent–child relationships, peer relationships) and SFVA symptoms in early and middle adolescence, as well as age differences. Results showed that SFVA3 *hard to control* and SFVA2 *increasing time for satisfaction* were the most central symptoms of SFVA in both early and middle adolescence. Among interpersonal relationships, teacher–student relationships and peer relationships exerted the largest impact on SFVA in early and middle adolescence, respectively. Comparison of the networks revealed no significant difference in overall network structures, global strength and most edge connections between early and middle adolescence. Our findings shed light on the pathway’s strength, central nodes of SFVA symptoms and bridge nodes among interpersonal relationships in different stages of adolescence, providing valuable insights into designing more precise, effective and timely preventions or interventions targeting SFVA. For students in early adolescence, open communication about screen time and media use given by teachers and parents are essential, like discussing with adolescents the time they spend in short-form videos and the content they watch, thus guiding them to view their usage critically. For students in middle adolescence, programs aimed at improving social skills, peer support networks, and group activities that engage adolescents in offline, healthy interactions could help reduce the risk of excessive screen time.

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