Smartphone Stress: Concept, Structure, and Development of Measurement Among Adolescents

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Abstract

People suffer from stress or digital stress when using information communication technology. Smartphones are the most widely used smart device among adolescents. However, few tools have been developed to capture smartphone stress. This preregistered study aims to clarify and define the concept of smartphone stress based on previous literature regarding digital stress and to develop a smartphone stress scale for adolescents. This study integrated qualitative and quantitative approaches to explore the structure of smartphone stress and develop a smartphone stress scale. First, we theoretically proposed the smartphone stress item pool based on current theories of digital stress and the definition of smartphone stress. Then, we conducted focus groups and in-depth interviews (N = 41) to revise the items in the item pool. Lastly, we finalized the scale based on the data collected from three independent samples of adolescents ($N_{sample1}$ = 1,088, $N_{sample2}$ = 879, $N_{sample3}$ = 176). The results revealed six dimensions of smartphone stress among adolescents: unsatisfactory information and communication, unmet recreational motivation, online learning burden, social concerns, useless and overloaded notifications, and online verbal attacks. The content validity was confirmed and the scale showed robust reliability (α = .851 to .959), stability (test-retest reliability = .717 to .681, p < .001), and validity (construct validity: χ^2 = 2,811.967, df = 399, CFI = .966, TLI = .963, RMSEA = .075; correlations with anxiety and depression were .431 to .462, p < .001). The developed scale is reliable in measuring smartphone stress in adolescents. Limitations, implications, and suggestions for future research are discussed.

Editorial Record

Introduction

When people live in such an era of digital media, it makes sense that the number of people using digital technologies will grow. Researchers have suggested that the rapid popularization of digital technology (e.g., computers, smartphones) has potentially negative effects on people's physical and mental health (e.g., stress,

depression, anxiety, sleep disturbance; Karsay et al., 2019; Lee et al., 2014; Thomée et al., 2007, 2011; Vahedi & Saiphoo, 2018; Wacks & Weinstein, 2021), and they have suggested that the negative mental health status might be associated with perceived stress, overload, or fatigue during digital technology use (Fox & Moreland, 2015; Xiao & Mou, 2019). Some concepts, such as social media fatigue (Xiao & Mou, 2019), information overload (Reinecke et al., 2017), Facebook-induced stress (Fox & Moreland, 2015), and mobile entrapment (Hall, 2017), technostress (Ragu-Nathan et al., 2008) have been used to describe these phenomena. Researchers have recently summarized these concepts and defined them collectively as digital stress (Steele et al., 2020). Digital stress has been found to be associated with mental health (Campisi et al., 2012; Fox & Moreland, 2015; Kushlev et al., 2019; Matthes et al., 2020; Reinecke et al., 2017; Steele et al., 2020). For example, Reinecke et al. (2017) revealed that in individuals aged 14–85 years, communication overload and internet multitasking will increase perceived stress, which then induces burnout and anxiety. Longitudinal evidence suggests that mobile social network use intensifies individuals' information overload, which affects depression and well-being (Matthes et al., 2020).

In the digital age, smartphones are the most representative type of media used by adolescents. The 2019 National Survey on Internet Use by Minors released by CNNIC (2020a) showed that the highest technology usage rate was for smartphones, at 93.9%. The usage rates of computers, laptops, and tablets among minors were 45%, 31.5%, and 28.9%, respectively. Adolescents can use smartphones to access almost all activities in the digital age and can be permanently online and permanently connected (Hefner & Vorderer, 2016). Rapid changes in brain structure and the mesocorticolimbic dopamine system during this period make adolescence a sensitive period for perceiving stress (Andersen & Teicher, 2008; Zimmer-Gembeck & Skinner, 2008). A recent study indicated that adolescents' perceived stress on social media may harm their mental health (Steele et al., 2020). Thus, it is necessary to investigate smartphone stress among adolescents, a self-report smartphone stress measure is particularly needed to capture adolescents' stress from smartphone use because self-report measures are simple, quick, low cost, and have irreplaceable advantages of obtaining the direct feelings of the individual experiencing the mental events or activities (McDonald, 2008). The rapid change during adolescence indicates that the validity and stability of the self-report measure also need identification. Besides, in the practice of health sciences, researchers usually developed full and short scales. Short scales are very common and convenient in studies, and they can save time by measuring fewer behaviors or items (Koğar, 2020). However, short scales may be less precise than full scales in terms of psychometric properties (e.g., reliability and validity) because the content and coverage of short scales are narrowed (Koğar, 2020). In addition, the development of short scales must be based on the full scales (Koğar, 2020). Thus, taking into account the previous suggestion (Koğar, 2020), we first developed a full smartphone stress scale among adolescents aged 10–18 years and then developed a short scale based on the full smartphone stress scale.

Smartphone stress is a form of digital stress (Steele et al., 2020) that dates back to the old term technostress (technostress can be defined as stress induced by the inability to adapt to the introduction and operation of new technologies) when computers began to attract people (Brod, 1982). Thus, developing the smartphone stress scale should be guided by the concept and structure of digital stress. Reviewing previous literature on digital stress can benefit to clarify and define the concept of smartphone stress and construct it theoretically. But, different studies have proposed different components of digital stress induced by digital media use according to different digital devices (e.g., computers, social media, Facebook; see Hefner & Vorderer, 2016; Reinecke et al., 2017; Steele et al., 2020; Tarafdar et al., 2020). Therefore, this study aims to review previous research on digital stress to help define the concept of smartphone stress, and develop a scale to measure smartphone stress among adolescents. The focus of this study was on smartphone stress in adolescents because adolescence is a critical developmental stage of life and smartphones are widely used among adolescents in China.

Digital Stress: The Definitions

The term "digital stress" first appeared in a study by Weinstein and Selman (2016), which used the thematic content analysis method to qualitatively study 2,000 anonymous posts on a website. Weinstein and Selman (2016) identified two main sources of digital stress: stress from relational hostility to cyberspace and stress from seeking relational connections. This seminal research did not define digital stress. Hefner and Vorderer (2016) pioneered the definition of digital stress by arguing that digital stress is the result of the cognitive demands emerging from digital communication technologies and behaviors that often exceed the cognitive resources of their users, such as being permanently connected to the internet, the excessive amount of available information, and the high load and fast speed of digital communication. Reinecke et al. (2017) proposed that digital stress is a stress response

caused by contextual demands during information communication technology (ICT) use. They believed that communication load and internet multitasking challenge users' sources of coping. Steele et al. (2020) also define digital stress as the subjective experience of an event, condition, or stimulus in the context of the individual's social and relational contexts and coping resources. In addition, researchers focused on occupational populations have used the term "technostress", which was defined as the inability to cope with the demands of organizational computer use (Ragu-Nathan et al., 2008).

Previous researchers have also proposed the components of digital stress based on their definitions of digital stress (see Table A1 in the appendix). There are many similarities between the components proposed by Hefner and Vorderer (2016) and Steele et al. (2020). They both emphasize stress from the aspect of interpersonal communication, fear of missing out, and self-presentation. The difference between them is that the former researchers proposed "multitasking", and the latter included "connection overload". The components proposed by Ragu-Nathan et al. (2008) differ from digital stress since their components are based on the work contexts. Furthermore, Fischer et al. (2021) reviewed previous research and developed a digital stressors scale in the workplace context, and they also proposed some new components of digital stress based on previous components of technostress (e.g., Ragu-Nathan et al., 2008). Because this study focuses on digital stress in adolescents, technostress in work conditions is not in our view. The digital stress components proposed by Tarafdar et al. (2020) not only focus on social media communication but also include the features of social media. Apart from those mentioned in Table A1, some qualitative studies have contributed to the components of digital stress. Weinstein and Selman (2016) proposed two types of digital stressors. The first type of stressor is related to relational hostility, and the second type of stressor is related to intimacy with others. We can summarize several common aspects of these definitions and components of digital stress: (1) They are all theoretically based on Lazarus and Folkman's (1984) concept of stress, where they consider stress as a situation in which the demands of the environment exceed the resources of the individual. (2) They all insist on using social media or social networking sites, and although some of them defined digital stress as coming from ICT, they explored digital stress mainly in terms of social media use or social network use (see Table A1). (3) Although some researchers have included components of digital stress, such as technological complexity, most of them have limited the concept of digital stress primarily to interpersonal or social interactions.

Digital Stress: Theoretical Background

Theoretical Basis

Previous research presenting the concept of digital stress is based on Lazarus and Folkman's (1984) theory of stress, where they assert that stress is when the demands of the environment exceed or tax the resources of individuals and threaten their well-being (see Hefner & Vorderer, 2016; Steele et al., 2020; Tarafdar et al., 2020). Although previous research has considered stress as a response to the environment, they have differently defined stress from the perspectives of cognitive response (Lazarus & Folkman, 1984), emotional response (Zastrow, 1984; Zautra, 2003), physiological response (Selye, 1950), and integrative medicine (Seaward, 2018). There are various definitions and measurements concerning stress (Sonnentag & Frese, 2013), some literature defines stress as a cognitive or emotional reaction and measures stress based on response measurement. We chose to measure stress based on self-reported emotional reactions. The reasons are as follows. First, cognitive reactions emphasize the cognitive process of spending time on assessment, which is similar to the cognitive-appraisal-coping model (Zautra, 2003). However, this model tends to underline the coping process rather than the stress process. Second, Zautra (2003) criticized cognitive-appraisal stress theory, arguing that analysis of and response to threats could be independent of conscious appraisal and faster, more automatic, and even more effective than appraisal-based emotional responses. Lazarus also incorporated emotions into the concept of stress in his later book. Negative emotions, such as anger, jealousy, or anxiety, may be referred to as stressful emotions because they usually arise from stressful conditions (Lazarus, 1999). Thus, as a type of stress, digital stress may be defined as a negative emotional response to the environment.

Furthermore, the definition based on Lazarus and Folkman (1984) emphasizes that individuals respond passively to the demands or challenges of their environment. However, after carefully examining the components of digital stress proposed by previous studies (Hefner & Vorderer, 2016; Ragu-Nathan et al., 2008; Steele et al., 2020), the components of digital stress that considered the stress theory of Lazarus and Folkman (1984) as the theoretical basis disclosed some controversial aspects. A major point of limitation is that the theoretical basis of digital stress

(stress originated from environmental demands on individual resources) fails to explain the components of digital stress. Taking Steele et al.'s (2020) components of digital stress (availability stress, fear of missing out, and approval anxiety) as examples, availability stress refers to the inability to be permanently availability and respond quickly during online communications, which can lead to stress. This component correctly follows Lazarus and Folkman's (1984) theory of stress, where individuals must respond quickly to meet the expectations of others (environment demands). Another component is approval anxiety, defined as uncertainty and psychological arousal about others' reactions to one's digital profile or footprint. This component emphasizes that individuals expect positive responses and reactions when providing a positive self-presentation (Hefner & Vorderer, 2016; Steele et al., 2020). This component did not underline the individuals' passive responses to environmental needs, but rather the extent to which one's needs were met by the environment (e.g., whether the users' need for self-presentation was met). Similarly, social comparison and fear of missing out focus on individuals' basic needs to improve their self-esteem and connection with others (Hefner & Vorderer, 2016). Therefore, Lazarus and Folkman's (1984) theory of stress may not be adequate as a theoretical basis for digital stress. The person-environment fit (P-E fit) theory (Edwards & Cooper, 1990) may be more appropriate as a theoretical basis for digital stress. P-E fit theory posits that stress not only from environmental demands that exceed or challenge an individual's resources (e.g., online interpersonal demands during communication), but also from a person's needs, interests, and values when they are not met by the environment (e.g., awareness of online stress from others one cares about, as suggested by the cost of caring theory (Hampton et al., 2015). The former has been described as an objective P-E misfit and the latter as a subjective P-E misfit (Edwards & Cooper, 1990).

In short, as smartphones are the most flexible and widely used digital device, adolescents not only receive various online demands that make them stressed (objective P-E misfit), but also will use smartphones to satisfy their demands (Kardefelt-Winther, 2014), once their demands cannot be met, they might also experience stress (subjective P-E misfit). Thus, the person-environment fit theory can be a theoretical basis for smartphone stress.

Smartphone Stressors

Lazarus and Cohen (1977) summarized three types of stressors: (1) major changes that are usually catastrophic and affect large numbers of people, such as natural disasters or wars; (2) major changes that affect one or a few people, such as the death of a loved one or divorce; and (3) daily hassles, those small things that irritate and bother people, such as feeling lonely and arguing with others. Besides, Wheaton and Montazer (2010) summarized the stress literature related to types of stressors over the past 40 years and ranked the different stressors according to a continuum of stress. From discrete to continuous, the types of stress include traumatic events, life change events, daily hassles, nonevents, chronic stressors, and chronic traumatic stress. According to previous research, a unique aspect of digital stress is permanent connectivity, so smartphone stress should be something like minor daily hassles or potential chronic stressors (Hefner & Vorderer, 2016). According to Lazarus and Folkman (1984), daily hassles mean that individuals have daily negative interactions with their surroundings. Wheaton and Montazer (2010) also noted that daily hassles span the realm of both events and more chronic problems and that they occupy an intermediate position on the stress continuum. In the field of technostress, researchers have used the concept of daily hassles to define technostress and developed the Computer Technology Hassles Scale to measure computer users' frustration caused by computer use (Hudiburg, 1989, 1992). Therefore, it is reasonable to define the type of smartphone stressors as digital "daily hassles".

In the digital age, smartphones provide not only contexts for social interaction but also digital scenarios for various nonsocial contexts, such as smartphone shopping, taking online courses by smartphones, playing smartphone games, browsing news and searching for information by smartphones. It is reasonable that these situations can also be part of smartphone stressors. For example, the theory of cost of caring suggests that awareness of stressful events in the lives of others can be a source of psychological stress (Hampton et al., 2016; Kessler et al., 1985) and that stress is contagious (Hampton et al., 2015). Researchers have found that smartphones provide people with the opportunity to be aware of the lives of near and distant social ties, and they experience stress from such awareness (Hampton et al., 2015, 2016). Thus, awareness of others' lives or stressful events from the internet suggests that smartphone stress is not limited to interpersonal interactions. In addition, Hefner and Vorderer (2016) mentioned that ubiquitous information or news connections may also induce stress, such as choice overload when shopping on smartphones, which also suggests that smartphone stressors should not just focus on social interactions like digital stress (e.g., Steele et al., 2020; Tarafdar et al., 2020) but also on non-social interactions (e.g., playing smartphone games). Thus, smartphone stress should encompass a variety of digital contexts (e.g., online chatting, online payment, playing smartphone games, online courses, online multitasking).

Research Gaps

As previously summarized, although previous research has made some contributions to the concept of digital stress, there are many other aspects of smartphone stress that need to be urgently addressed. First, some concepts or components in previous digital stress may not be appropriate for adolescents. Second, smartphone stress may not be limited to interpersonal aspects, non-interpersonal aspects could also be part of smartphone stress. And the classification of smartphone stress could be a type of "daily hassles" stress. Third, the existing theoretical basis of digital stress is not enough for smartphone stress. Fourth, since smartphones are the most widely used media devices among adolescents, investigating their stress suffering from smartphones is of great importance. Few previous studies focus on adolescents' digital stress or smartphone stress and there exist no measures for adolescents' smartphone stress. To solve these gaps, smartphone stress needs to be redefined and a scale measuring smartphone stress should be developed. In this way, researchers and the public can deeply understand what adolescents' smartphone stress is, and it may promote future related research (e.g., understanding the prevalence of adolescents' smartphone stress and its relationship with mental health). Thus, this study conceptualizes "smartphone stress" and develops a smartphone stress scale.

Definition and Measurement of Smartphone Stress

Building on the preceding review of digital stress, we define smartphone stress as *a negative emotional response perceived or experienced daily by an individual during the process of using various functions or contents on smartphones, which is either a passive response to the demands of the smartphone use contexts or a failure of the smartphone use contexts to meet the individuals' demands or interests*.

There are few measurements that assess individuals' smartphone stress status. For example, Hampton (2016) argues that social media can induce stress, but they indirectly measure digital media stress through the Perceived Stress Scale, a well-known measure of personal stress in general life (Cohen et al., 1983). Previous research has developed tools to measure concepts such as communication overload (Reinecke et al., 2017), Facebook-related stress (Beyens et al., 2016), social networking site stressors (Tarafdar et al., 2020), and technostress (Ragu-Nathan et al., 2008). Recently, a multidimensional digital stress scale was developed and it measures availability stress, approval anxiety, fear of missing out, connection overload, and online vigilance (Hall et al., 2021), but it is based on social media, and do not purely focus on adolescents, and omits stress from non-social online activities. These measures measure the different constructs of digital stress, some of which may be suitable for smartphone stress in adolescents (e.g., components related to interpersonal interactions, multitasking, connection overload), but others may not be appropriate for adolescents because these components come from the workplace (e.g., techno-insecurity). Therefore, it is urgent to develop a smartphone stress scale to evaluate stress from smartphones most widely used by adolescents.

The Present Study

To understand the structure and components of adolescents' smartphone stress and promote further research in this file (e.g., investigation of the relationships between smartphone stress and adolescents' health and development), this study aims to develop a scale based on the concept of smartphone stress proposed in this paper. This study first theoretically proposes a potential structure of smartphone stress based on the definition of smartphone stress and related studies and tries to prepare an "item pool" of smartphone stress. Second, through focus groups and in-depth interviews, qualitative material from adolescents was collected to revise the theoretically proposed "item pool". Third, the content validity was confirmed and three questionnaire investigations were conducted to explore and confirm the structure of smartphone stress and to develop a smartphone stress scale. Fourth, the reliability and validity of the developed scale were confirmed.

In our study, P-E fit theory was used to guide each step. We rooted P-E fit theory to guide our theory construction and the process of defining smartphone stress (e.g., we only emphasized negative emotional reactions, and did not unilaterally emphasize objective P-E mismatch aspects or subjective P-E mismatch aspects, both of which are naturally considered; we also provided the cost of caring theory as a theoretical basis for subjective P-E mismatch), the process of interviewing (e.g., during the interview, we simply asked the adolescents to talk about their negative emotions or feelings of stress in various contexts of smartphone use, which suggests that both objective P-E

mismatch and subjective P-E mismatch were naturally included), and the process of creating items (e.g., items considering objective P-E mismatch and subjective P-E mismatch were included).

Method

Theoretically Proposing the "Item Pool" of Smartphone Stress

Considering the definition of smartphone stress, we emphasized various smartphone use contexts and negative emotional reactions. Based on previous international reports and literature, several digital contexts on smartphones were identified. First, we referred to the 46th Statistical Reports on Internet Development in China (CNNIC, 2020b), the 2019 Report on the Internet use of Chinese Minor (Ji et al., 2020), the PISA 2021 ICT Framework (OECD, 2019), the TIMSS 2019 Assessment Framework (Mullis & Martin, 2019), and other materials related to multitasking (Hefner & Vorderer, 2016; Pflügner et al., 2021) and information overload (Larose et al., 2001; Misra & Stokols, 2012; Pflügner et al., 2021; Reinecke et al., 2017; Steele et al., 2020). We found that CNNIC classified smartphone use into four digital contexts, including online learning (e.g., online courses), entertainment (e.g., watching TVs, watching clips, etc.), social interaction (e.g., online chat), and online consumption (e.g., online payment). Based on TIMSS 2019, PISA 2021 ICT framework, and the existing literature about multitasking, we revised the digital contexts in CNNIC into five areas: social interaction, entertainment, learning, consumption, and multitasking. While previous literature referred to information overload and security of ICT use, the present study integrated them into each classification of smartphone use contexts. Although previous literature has referred to information overload and security of ICT use, the present study integrated them into each of the classifications of smartphone use contexts. Second, Lazarus (1991) proposed nine stress emotions (negative emotions), including anger, anxiety, fright, guilt, shame, sadness, envy, jealousy, and disgust. Zastrow (1984) proposed four emotional stress reactions, encompassing tension, anxiety, worry, and alertness. Thus, 121 items related to smartphone stress are constructed and are a combination of various digital contexts and potential negative emotional reactions in such contexts, which covers the concept of smartphone stress mentioned in previous literature. For example, "Others' Wechat Moments have more likes than me" is a typical example of social media-based comparison among children and adolescents in the context of Chinese culture. A two-way specification table was used to present the combinations of digital contexts and emotional reactions during item generation. In this table, 40 items, 35 items, 26 items, 10 items, and 10 items were identified for five digital contexts (social interaction, entertainment, learning, consumption, and multitasking), and six negative emotions (anger, anxiety, fright, sadness, envy/jealousy, and disgust) were used. In this process, P-E fit theory was also incorporated, for example, negative emotions caused by objective P-E misfit or subjective P-E misfit were taken into account in each digital context.

Qualitative Research

This part consisted of focus group interviews and personal in-depth interviews. First, the focus group was considered pre-interview designed to characterize the stressors adolescents perceived while using smartphones, to inform the formal in-depth interviews later, and to improve the quality of the formal in-depth interviews. Each focus group was set up in a quiet room and participants were told that for the next 40–60 minutes, we would focus on what kind of pressure they encountered and what kind of negative experiences (emotions) they had while using their smartphones and that this process would be recorded and no one other than the researchers would have to access the recorded material. Six middle school students (male = 3) and six high school students (male = 3) participated in two separate focus groups (December 2020). The results of the focus group interviews suggest that adolescents do experience some negative emotions or feel stressed when using their smartphones for some activities. And just asking students some open-ended questions may not fully recall their stressful experiences on their smartphones (e.g., did you have any negative emotions or some awful emotions while using your smartphone?). So in the next in-depth interviews, we added questions about specific digital contexts (e.g., do you have negative emotions when using smartphones for an online course?) to help students recall their experiences and emotions. Second, the in-depth review was a formal review. The objectives of the in-depth interviews were similar to those of the focus groups in which participants were asked to talk about negative emotions or stress they experienced while participating in online activities with smartphones. The interviews with each participant were conducted in a quiet room, were audio-recorded, and lasted 40–60 minutes. The material from the in-depth review was used to modify our theoretically proposed smartphone stress items. We recruited 29 adolescents (17

middle school students, males = 9; 12 high school students, males = 6; M_{age} = 13.93) for personal in-depth interviews (December 2020). All adolescents surveyed in this study were Chinese, and informed consent was obtained from all participants. For more detailed information about interviews (e.g., open questions, introductory questions, critical questions in the focus group; open-ended review part, structured interview part in in-depth review), readers can visit the pre-registered link (https://osf.io/k37cr) and related files (https://osf.io/r69wm/).

The material obtained from the formal interviews was coded and analyzed using NVivo 11 software, a convenient tool for processing qualitative data (AlYahmady & Alabri, 2013). The results of Nvivo analysis are listed in Table A2 (see appendix). Based on the qualitative material, of the 121 theoretically constructed items, we excluded items that were not related to the qualitative material and invited four developmental psychology PhDs familiar with ICT use and adolescents' development to evaluate the reasonableness of the retained items in a roundtable discussion (e.g., using more appropriate expressions for negative emotions, the check whether the items reflect aspects of P-E fit theory and whether the items are appropriately expressed). Finally, a total of 84 items (using a 4-point Likert scale (1 = *never*, 2 = *occasionally*, 3 = *frequently*, 4 = *always*) were finally included in the "item pool".

Questionnaire Research

Participants

In the first survey (March 2021), 1,156 adolescents (1,088 valid participants, M_{age} = 14.89 ± 1.40, male = 554, age range = 10–18 years) participated in our online survey. The link to the online survey was sent to the students with the assistance of their teachers, and the students completed the survey online. The online survey was used due to the local government's policy of lockdown on the recurrence of COVID-19 in March 2021. The average response time was 12.19 minutes, and we excluded 68 students whose average response time per item was less than 2 seconds because they were unlikely to respond faster than 2 seconds per item (Huang et al., 2012). In the second survey (April 2021), 897 (M_{age} = 14.03 ± 1.36, male = 456) adolescents took part in our offline survey, completing the smartphone stress scale and other scales related to convergent validity and criterion validity. Students completed a paper-and-pencil questionnaire, and the teacher helped to collect the completed questionnaires. In the third survey (April 2021), 176 adolescents who participated in the second survey were resurveyed to obtain the retest reliability of the Smartphone Stress Scale (with a one-week interval between wave 2 and wave 3 according to previous research (Marx et al., 2003). The adolescents in Survey 1 and Survey 2 were from different schools. All adolescents surveyed in this study were from the eastern (7.6%), northern (47.71%), and southwestern (44.69%) regions of China, and 51.2% were from urban areas. Informed consent was obtained from all the participants.

Measurement of Validity

According to previous research on digital stress (Reinecke et al., 2017), anxiety and depression were regarded as criterion validity of the smartphone stress scale and were measured in the second and third investigations of this study. We used the Generalized Anxiety Disorder-7 scale (GAD-7; Spitzer et al., 2006) and the Center for Epidemiologic Studies Depression Scale (CES-D-10; Andresen et al., 1994) to measure anxiety and depression in adolescents, respectively. The GAD-7 includes 7 items and items were rated using a 5-point Likert scale (α = .963). The CES-D-10 includes 10 items and items using a 4-point Likert scale (α = .843). The appropriateness of these two scales has been confirmed among Chinese adolescents and is widely used among Chinese researchers (Lai et al., 2022).

We revised the Social Network Site Stress Scale (SNSS; Tarafdar et al., 2020) to measure adolescents' perceived stress during SNS use. The SNSS was translated into Chinese by two master's students with good English proficiency and then examined by four PhDs familiar with ICT use. It includes 23 items and 6 dimensions (social overload, disclosure, pattern, complexity, uncertainty, invasion) and uses a 4-point Likert scale to assess the items (α = .907). An example item is *There is more information on social media than I can digest*. The SNSS was used as a convergent validity for the smartphone stress scale.

First, according to the rule of factor analysis, to ensure the stability of a factor solution, researchers should have at least a 4:1 ratio of subjects to variables (MacCallum et al., 2001). A sample size greater than 500 is very good in factor analysis (Comrey & Lee, 1992). Therefore, 600 participants were randomly selected from the first survey to conduct an exploratory factor analysis (EFA). The EFA procedure followed the steps proposed by Suhr (2006). A total of 1,088 participants were used for the confirmatory factor analysis (CFA), the WLSMV estimation method was used and the 2nd order reflective-reflective CFA model (Sarstedt et al., 2019) was implemented for the full scale. Second, considering that the full smartphone stress scale has somewhat too many items, a short form of the smartphone stress scale was developed. The items of the short version were selected based on the explanatory variance of each dimension and the correlation between the items and the total smartphone stress score (Foerster et al., 2015). Third, data from the second and third surveys were used to assess the reliability and validity (criterion validity, convergent validity, and discriminant validity) of the scale. All analyses were performed in SPSS 25.0 and Mplus 7.0 software. The development of the smartphone stress scale was preregistered at https://osf.io/tfhd4.

Results

EFA and CFA

The EFA (84 items) showed that 11 factors had eigenvalues greater than 1 (using the principal axis factor method). After factor rotation (using Oblimin with Kaiser normalization) and removal of items with loadings below 0.3, redundant items, and items with cross-loadings (reducing redundant items beneficial for improving validity (Neill & Jackson, 1976) and avoiding response bias due to responding in a certain way (Baird & Lucas, 2011), six factors were ultimately extracted, and 39 items were retained. During the process of reducing redundant items or items with cross-loadings, we ensured that each theoretical aspect had corresponding items. To further reduce the items and reduce the redundancy between items in the same factors, according to the suggestions by Domoff et al. (2019), to further reduce items and redundancy in the same dimensions, items with higher loadings should be reserved. Therefore, 4 items, 3 items, and 1 item were excluded from factor 1, factor 2, and factor 4, respectively. Ultimately, 30 items were retained, which could explain 71.7% of the variance. According to the rules of the development of a short version of the scale (Foerster et al., 2015), the higher the variance explained by a factor, the more items should be selected in that factor for the short version, and the items selected should also consider the correlation between the items and the total score of the full scale. In the short version, three items on factor 1 were selected, two items on factor 2 were selected, and one item was selected from the left of each factor (see Table 1).

CFA revealed good model fit for both the full scale (χ^2 = 2,811.967, *df* = 399, CFI = .966, TLI = .963, RMSEA = .075) and the short version (χ^2 = 175.509, *df* = 25, CFI = .991, TLI = .988, RMSEA = .074) scales. In the CFA, the standardized factor loadings ranged from .623 to .904 for the full scale (see Figure A1 in the appendix) and from .562 to .841 for the short version of the scale (see Figure A2 in the appendix). In addition, in the other sample, the full scale (χ^2 = 2,204.409, *df* = 398, CFI = .943, TLI = .937, RMSEA = .072) and the short scale (χ^2 = 54.132, *df* = 24, CFI = .994, TLI = .991, RMSEA = .038) also had very good construct validity (see Table 2).

Factor analysis identified six components of smartphone stress among adolescents (see Table 1). Unsatisfactory information and communication (factor 1, explaining 47.75% of the variance) refers to stress caused by exhausted communication and unsatisfied information needs during smartphone use. Unmet recreational motivation (factor 2, explaining 6.8% of the variance) refers to stress arising from irritated aspects that hinder adolescents' recreational aims, especially when playing games on smartphones. Online learning burden (factor 3, explaining 5.49% of the variance) shows that adolescents suffer from stress when using smartphones for learning. Social concern (factor 4, explaining 5.29% of the variance) implies that adolescents suffer from stress when they pay excessive attention to what they care about while using their smartphones. Useless and overloaded notifications (factor 5, explaining 3.64% of the variance) highlights the stress triggered by receiving useless information or overloaded notifications while using smartphones. Online verbal attacks (factor 6, explaining 2.74% of the variance), the last factor, reveals stress triggered by receiving or being involved in verbal attacks or comments while using smartphones.

Table 1. *Factor Loadings From EFA.*

Items	F1	F2	F3	F4	F5	F6
I1. Being unable to communicate clearly on my smartphone makes me anxious†	.785					
I2. It makes me sad that I cannot communicate clearly on my smartphone	.732					
I3. I feel irritated when I search out inconsistent content on my smartphone†	.622					
I4. I feel irritated when I cannot communicate clearly on my smartphone	.650					
I5. I feel anxious when I cannot find the information I want on my smartphone	.585					
I6. I feel sad that I cannot find the information I want through my smartphone†	.532					
I7. The uncooperative behavior of teammates in mobile games makes me irritated		.744				
I8. Being interrupted while playing mobile games makes me feel irritated		.730				
I9. I feel angry when my teammates do not cooperate while playing mobile games†		.716				
I10. Losing mobile games makes me angry†		.658				
I11. Losing mobile games makes me sad		.625				
I12. People messaging or calling me while I play games on smartphone irritates me		.577				
I13. Online classes' failure to solve my study problems on the smartphone platform frustrates me			.812			
I14. Online classes' failure to solve my study problems on the smartphone platform irritates me†			.715			
I15. I feel irritated when using my smartphone to complete complicated assignments			.551			
I16. I am angry at spending enormous amount of time to complete online classes on my smartphone			.477			
I17. Seeing negative news about someone or something I care about in a short video on my smartphone makes me sad				.871		
I18. Seeing negative news about someone or something I care about in my mobile news feeds makes me sad				.860		
I19. Seeing negative news about someone I care about while browsing social media on smartphones makes me sad				.880		
I20. Seeing negative news about someone or something I care about in a short video on smartphone makes me feel disgusted				.745		
I21. Seeing negative news about someone or something I care about in a short video on my smartphone makes me feel anxious				.694		
I22. It makes me feel sad to see others insult, attack, or make mean comments about people I care about while browsing social media†				.624		
I23. The advertisements pushed by my mobile news feeds irritate me					.859	
I24. The advertisements pushed to my mobile news feeds make me angry†					.767	
I25. I am tired of the huge amount of information pushed to my mobile news feeds					.734	
I26. I am fed up with the large amount of irrelevant information that appears when I search on my phone					.613	
I27. I am sick of the malicious comments (e.g., abusive or offensive comments) in the comments section of short clips on my phone						.748
I28. Bad comments (e.g., abusive or offensive comments) in the comments section of short videos on my phone make me angry†						.716
I29. I am offended by the people's bad language and behaviors (e.g., verbal abuse) when communicating on a mobile phone						.594
I30. Bad verbal behaviors (e.g., abusive comments) when communicating on mobile phone make me feel disgusted						.556

Note. † items from the short version scale. F1 = Unsatisfactory information and communication, F2 = Unmet recreational motivation, F3 = Online learning burden, F4 = Social concerns, F5 = Useless and overloaded notifications, F6 = Online verbal attacks.

Reliability and Validity

Table 2 presents the reliability and construct validity of the smartphone stress scale, which was very reliable for both the full scale and the short scale. Cronbach's α for the full scale ranged from .943 to .959 across samples, and it also had good test-retest reliability ($r = .717$, $p < .001$). For the short version of the scale, Cronbach's α ranged from .851 to .934, and it also had good test-retest reliability ($r = .678$, $p < .001$). Table 3 presents the validity conditions of the smartphone stress scale. Scores on both the full scale and the short scale were positively correlated with scores on anxiety and depression ($r = .431$ to .462, $p < .001$) and SNS stress ($r = .348$ to .361, $p < .001$). Scores on the six dimensions of the full scale were also positively correlated with scores on anxiety and depression ($r = .216$ to .459, $p < .001$) and SNS stress ($r = .059$ to .323, $p < .001$). The further relationships between smartphone stress (and SNS stress) and anxiety/depression were presented in Table A3 (see appendix). Besides, the average variance extracted (AVE) ranged from .728 to .829 (greater than .50; Mackenzie et al., 2011; see Table A4 in appendix), and the heterotrait-monotrait (HTMT) ranged from .343 to .801 (less than .85; Henseler et al., 2015; see Table A5 in appendix). These findings indicate that the scale has good criterion, convergent, and discriminant validity.

Additionally, the correlations between the full version and the short version were .963 ($p < .001$), .953 ($p < .001$), and .964 ($p < .001$) across the three samples. The smartphone stress scale is presented in appendix (Figure A1, Figure A2), and the Chinese version of the scale is presented in the supplementary materials.

Table 2. *Reliability and Construct Validity of Smartphone Stress Across Samples.*

	Version	α	Stability	χ^2	df	CFI	TLI	RMSEA
Sample 1	Full	.959	—	2,811.967***	399	.966	.963	.075
(N = 1,088)	Short	.900	—	175.509***	25	.991	.988	.074
Sample 2	Full	.943	—	2,204.409***	398	.943	.937	.072
(N = 879)	Short	.934	—	54.132***	24	.994	.991	.038
Sample 3	Full	.956	.717**	—	—	—	—	—
(N = 176)	Short	.851	.678**	—	—	—	—	—

Note. *** $p < .001$. The α of the six subscales (factor 1 to factor 6) sequently is .924, .895, .828, .925, .863, .913 in sample 1 and sequently is .810, .889, .714, .887, .856, .887 in sample 2, sequentially .870, .914, .801, .991, .883, .899 in sample 3.

Table 3. *Correlations Between Smartphone Stress Scale and Other Related Validities.*

	F1	F2	F3	F4	F5	F6	Short version	Full version
Anxiety	.459**	.312**	.407**	.336**	.295**	.257**	.443**	.462**
Depression	.449**	.334**	.411**	.297**	.265**	.216**	.431**	.443**
Social overload	.293**	.235**	.244**	.323**	.125**	.208**	.324**	.327**
Disclosure	.280**	.132**	.238**	.202**	.246**	.241**	.288**	.295**
Pattern	.232**	.143**	.175**	.179**	.121**	.125**	.231**	.220**
Complexity	.142**	.002	.137**	.123**	.037	.109**	.104**	.118**
Uncertainty	.177**	.095**	.113**	.208**	.173**	.246**	.196**	.227**
Invasion	.294**	.223**	.247**	.275**	.138**	.187**	.296**	.310**
SNSS	.341**	.201**	.280**	.320**	.198**	.268**	.348**	.361**

Note. ** $p < .001$, SNSS = social network site (SNS) stressor.

Discussion

This study reviewed previous literature related to stress and digital stress and further clarified the concept of smartphone stress. This study then theoretically presented a potential structure of smartphone stress among Chinese adolescents and revised this structure through interviews to develop the main items of smartphone stress. Next, this study implemented an EFA to explore the structure of smartphone stress and to assess its

reliability and validity using a rigorous analytical approach. Finally, a full smartphone stress scale containing 30 items in six dimensions was defined, and a short smartphone stress scale with 9 items in one dimension was developed.

The dimensions of the developed smartphone stress scale had some similarities to previous studies. This study found that factor 1 explained most of the variance, which partially supports previous arguments that digital stress comes primarily from online interpersonal interactions (Hefner & Vorderer, 2016; Steele et al., 2020; Tarafdar et al., 2020). However, factor 1 also identified an aspect of unsatisfactory information demand. Factor 5 revealed that useless information or notifications and overloaded notifications may increase adolescents' smartphone stress, which is also partially consistent with the information overload suggested by previous research (Larose et al., 2001; Misra & Stokols, 2012; Pflügner et al., 2021; Reinecke et al., 2017; Steele et al., 2020). However, factor 5 also highlighted the uselessness of overloaded information. Factor 6 shows verbal attacks during smartphone use, a factor consistent with the work of Weinstein and Selman (2016). Their textual analysis concluded that relational hostility in cyberspace is a common digital stressor. They noted this kind of stressor consists of "mean and harassing personal attacks" and "public shaming and humiliation".

The study also described three unique aspects of the structure of smartphone stress that differ from previous components, including F2 (unmet recreational motivation), F3 (online learning burden), and F4 (social concerns). Factor 2 contained stress while playing games, such as uncooperative behavior of teammates, losing a game, or being interrupted by other things. Additionally, multitasking on smartphones is also shown in this dimension (e.g., *playing games and simultaneously sending a message*). While there is something novel about Factor 2, being interrupted during smartphone use is consistent with a previous concept—"interruptions during the use of information technology in work situations", which defines information technology interruptions as perceived information technology-based external events that draw cognitive attention and break the continuity of the primary tasks at hand (Addas & Pinsonneault, 2015, 2018). Factor 3 contained stress when taking online courses via smartphones. This aspect has often been overlooked by previous research in regard to digital stress in adolescents. A core task for adolescents is to continue learning, so it makes sense for adolescents to use their smartphones for learning, but this use can also trigger stress. Factor 4 contains the stress that occurs when adolescents learn about the bad aspect of something they care about in the course of using their smartphones. Why are these three dimensions so prominent and unique? First, there are no relevant studies to prove that these three components can be sources of smartphone stress (see a review, Steele et al., 2020). Second, empirically, it is reasonable for these three components to induce smartphone stress. The 2019 National Study on Internet Use by Minors (CNNIC, 2020a) shows that among their online activities using smartphones, taking online courses ranks first among adolescents' online activities, at 89.6%; playing games and listening to music are the main recreational online activities, at 61% and 65.9%. Therefore, with such activity intensity, taking online courses and playing smartphone games are likely to trigger stress. In addition, factor 4 is consistent with the theory of the "cost of caring". This theory claims that stress occurs when individuals are overly concerned about the people and events around them, as these behaviors can drain individuals of their sympathy and lead to psychological stress (Hampton et al., 2016). Digital emotional contagion underlines that individuals are also affected when they are exposed to the emotional expressions of others on digital media (Goldenberg & Gross, 2020), especially exposure to negative emotions (e.g., anger) among weak social network ties (Fan et al., 2020).

Notably, the structure we found does not contain some of the components proposed by previous researchers, such as availability anxiety (Hefner & Vorderer, 2016; Steele et al., 2020). We believe there are two reasons for this. First, the adolescent population may be different from the college or adult populations. Previous research has shown that availability anxiety is associated with the use of texts to maintain larger social networks (Hall, 2017). For adolescents, the number of social relationships is relatively less than that of adults or college students. Thus, availability anxiety may be less important in adolescents. Second, previous results revealing that social comparisons and mobile maintenance expectations are associated with stress have been found primarily in adults or college students (see Feinstein et al., 2013; Fox & Moreland, 2015; Hall, 2017; Hall & Baym, 2012).

Implication

This study has several theoretical and practical implications. Theoretically, this study not only systematically elucidates the concept of smartphone stress but also rigorously explores the structure of smartphone stress and develops a measurement method to evaluate the level of smartphone stress in Chinese adolescents. On the one hand, this study improves the theoretical basis of smartphone stress through the elucidation of the person-

environment fit theory. Previous studies regard the theoretic basis of digital stress as the mismatch between digital environmental demands and individual resources. While this study borrowed P-E fit theory and suggested that digital stress can be from not just the mismatch between digital environmental demands and individual resources but also the mismatch between individual demands and the environmental supply. On the other hand, this study extended smartphone stressors by transforming digital contexts from interpersonal interactions during social media use to various smartphone use contexts (e.g., non-interpersonal interaction contexts such as online games, online study, and social concern). Indeed, the clarification of the concept of smartphone stress and the development of a smartphone stress scale revealed new components of digital stress (e.g., social concern, online learning burden) and supplemented existing digital stress scales by extending the digital contexts into non-interpersonal digital contexts (e.g., online games and online learning). Besides, previous studies mainly focused on adults, while this study, by focusing on adolescents, firstly revealed the adolescents' stress suffering from smartphones, which increases the group diversity of digital stress. Previous research has shown that digital stress is negatively associated with mental health (Steele et al., 2020). This study clarified the concepts and developed measurement methods to assess smartphone stress and may help researchers delve deeper into the relationship between smartphone stress and mental health.

Limitation

First, the smartphone stress scale developed is based on popular smartphones, it has its own range of applicability. Second, this study only explored the smartphone stress structure in Chinese adolescents. Caution should be exercised when the smartphone stress structure in this study is used in different populations, as smartphone stress may differ in different populations.

Future Direction

Baym (2010) pointed out that the relationship between technology and society follows four steps: (1) Technological determinism. Humans have little power to resist the influence of new technology. (2) Social construction of technology. People are the main sources of change in both technology and society. (3) Social shaping. People and technology influence each other. (4) domestication. People accept technology and take it for granted. Take smartphones as an example. According to a report by Statista (2020), the number of smartphone users worldwide will increase from 1.06 billion in 2012 to 4.5 billion in 2023. Such a leap change over the past 20 years suggests that smartphones may be in their fourth stage of development in terms of the relationship between technology and society, where people accept them and take them for granted. Therefore, in this context, the first question is how many adolescents suffer from smartphone stress as smartphones deeply penetrate every aspect of people's lives. How prevalent is smartphone stress? Second, since previous research illustrates that digital stress is related to mental health, what kinds of influencing mechanisms exist between smartphone stress and mental health? Third, as previous literature indicates that digital stress may negatively impact adolescents' mental health (Hall et al., 2021; Nick et al., 2022), what approaches should be taken to prevent this phenomenon? Fourth, most previous studies have been interested in problematic smartphone use or smartphone dependency (see Busch & McCarthy, 2021; Guitton, 2020). What is the relationship between smartphone stress and problematic smartphone use? What are the mechanisms of approach-avoidance conflict on smartphones? Fifth, since the interest of this study is Chinese adolescents, what would be the structure of smartphone stress for other populations, such as adults or older adults? Is the scale developed in this study applicable to adolescents from other cultural backgrounds? All the above questions deserve to be explored and answered in future studies. The good reliability and validity of the short and full smartphone stress scale indicate that the scale would be useful and flexible in future studies to help solve the above questions, and when it was used in other cultural contexts or populations, the validation needs further confirmation.

Conflict of Interest

The authors have no conflicts of interest to declare.

Authors' Contribution

Shunsen Huang: conceptualization, investigation, data curation, formal analysis, methodology, visualization, writing—original draft, writing—review & editing. **Xiaoxiong Lai:** conceptualization, investigation, data curation, study supervision, resources, validation, writing—review & editing. **Li Ke:** investigation, writing—review & editing. **Xubao Qin:** investigation. **Jia Julia Yan:** writing—review & editing. **Yumei Xie**: investigation, resources. **Xinran Dai:** writing—review & editing. **Yun Wang:** conceptualization, writing—review & editing, study supervision, project administration.

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Appendix

Table A1. *Components of Digital Stress Proposed in Previous Research.*

(Hefner & Vorderer, 2016)		(Steele et al., 2020)		(Ragu-Nathan et al., 2008)		(Tarafdar et al., 2020)	
Digital stress		Digital stress		Technostress (work condition)		Technostress (nonwork condition)	
Components	Detailed information	Components	Detailed information	Components	Detailed information	Components	Detailed information
Accessibility and reactions to communication demands	Quick response to follow others' expectations or social standards	Availability stress	Availability demands placed on mobile device users	Techno-overload	ICTs force users to work faster and longer	Social overload	Users respond to too many requests through the SNS for social support
Continuous communication vigilance	Permanent vigilance for incoming messages due to fear of being excluded from the stream of communication	Fear of missing out	Fear of being excluded from what others are engaged in	Techno-invasion	Invasive effect of ICTs in situations related to users' personal lives	Disclosure	Individuals' feeling that they get too much information on SNS
Permanently reconsidering and presenting the self	Permanent self-presentation and negative social comparison	Approval anxiety	Uncertainty and psychological arousal about others' responses and reactions to ones' posts	Techno-complexity	ICTs leads users to feel inadequate regarding their computer skills	Pattern	Individual adapts his or her use of SNS to conform to his or her friends' use
Multitasking	Simultaneous execution of multiple tasks demanding cognitive capacity	Connection overload	The amount of information available exceeds the capacity of the individual	Techno-insecurity	The perceived threat of losing one's job due to a lack of ICT skills	Complexity	Users perceive SNS as technically difficult to use
				Techno-uncertainty	Continuing ICT changes and upgrades create uncertainty	Invasion	Individuals feel that their personal life is being invaded by SNS

Table A2. *Coding of Qualitative Materials in NVivo 11.*

Sources of stress	Detailed information *(Example of interview materials)*	Nodes	References
Fake or bad information and calls	Harmful/bothered/fake information (e.g., *I sometimes receive fraudulent phone calls, this bother me*)	20	24
Multitasking	Implementing several activities simultaneously with smartphones (e.g., *when I play smartphone games and simultaneously have to chat with others, it annoys me*)	21	32
Social concerns	Seeing negative news of the one people care about from multiple sources, such as forums, social media, comments, clips, or videos (e.g., *seeing negative news (e.g., the death of a star) I care about often makes me sad*)	23	64
Social interaction	Others' online offensive behaviors (e.g., *others sending some aggressive texts when chatting online makes me angry*)	3	3
	Stress from receiving and sending messages (e.g., *if my friends do not reply to my message for a long time, I will feel anxious*)	7	8
	The inconvenience of nonface-to-face communications (e.g., *I feel stressed when online chat fails to express my intentions like face to face*)	12	20
	Self-presentation and social comparison (e.g., *others did not give me a "like" or I receive few "likes" or "comments", which makes me a little sad..."*)	10	12
Online spending	Feeling stressed during online consumption (e.g., *... for example, sometimes receiving goods of poor quality can make me feel angry...*)	9	12
Unmet information demands	Feeling irritable when the use of smartphones fails to meet demand. (e.g., *... it makes me angry and irritable when I fail to find the information I want when using smartphone search engines...*)	14	20
Information overload	Receipt of too much information when using smartphones. (e.g., *... there are numerous messages in shopping apps, and it makes no sense to me..., it makes me feel bothered...*)	14	19
Learning through smartphones	Messages from class's WeChat groups *(e.g., my teachers often release some bothersome tasks on the Group Announcements..., sometimes the messages in a WeChat group will be replicated many times, which makes me feel bothered and annoyed)*	8	12
	Taking online courses through smartphones (e.g., *taking online courses will take me much time..., it makes me burdened...*)	13	24
	Completing homework through smartphones (e.g., *... sometimes my teachers will require us to complete some tasks through smartphones, which makes me feel difficult to operate and irritable...*)	7	11
Playing games on smartphones	Others' unfriendly behaviors in playing games on smartphones (e.g., *... in team games, my randomly matched teammates will attack me verbally or textually..., this often make me sad and irritated*)	8	8
	Losing the game (e.g., *... losing games on smartphones makes me feel stressed and angry..., if my teammate I matched with is a bad player, I usually feel angry and irritable*)	19	29

Note. Nodes represent the number of interview materials or participants, and there were a total of 29 nodes for we investigated 29 interviewers. References represent how many times the interviewed materials reveal the theme or the sources of stress.

Table A3. *Regression Results.*

Independent variables	Smartphone Stress Scale			Independent variables	SNSS scale		
	Anxiety	Depression			Anxiety	Depression	
	β	β	VIF		β	β	VIF
F1	.335***	.276***	2.099	Social overload	.219***	.165***	1.583
F2	.083*	.105***	1.407	Disclosure	.068	.048	1.680
F3	.206***	.185***	1.767	Pattern	-.002	-.004	1.955
F4	.150**	.101**	2.012	Complexity	.001	.044	1.566
F5	.048	.011	1.610	Uncertainty	.000	-.003	1.210
F6	.065	.079*	2.066	Invasion	.144**	.164***	1.752

Note. *** $p < .001$. ** $p < .01$. *$p < .05$. F1 = Unsatisfactory information and communication, F2 = Unmet recreational motivation, F3 = Online learning burden, F4 = Social concerns, F5 = Useless and overloaded notifications, F6 = Online verbal attacks.

**Table A4.** *The AVE Values for Each Dimension (Values in Diagonal Line).*

	F1	F2	F3	F4	F5	F6
F1	0.794					
F2	.496**	0.728				
F3	.614**	.414**	0.74			
F4	.515**	.307**	.441**	0.791		
F5	.496**	.403**	.461**	.341**	0.728	
F6	.461**	.329**	.398**	.657**	.494**	0.829

Note. ** $p < .001$.

Table A5. *The HTMT Between Dimensions.*

	F1	F2	F3	F4	F5	F6
F1	1					
F2	.588	1				
F3	.801	.520	1			
F4	.604	.343	.557	1		
F5	.583	.456	.591	.392	1	
F6	.540	.368	.499	.740	.571	1

Figure A1. Model Structure of the Full Smartphone Stress Scale.
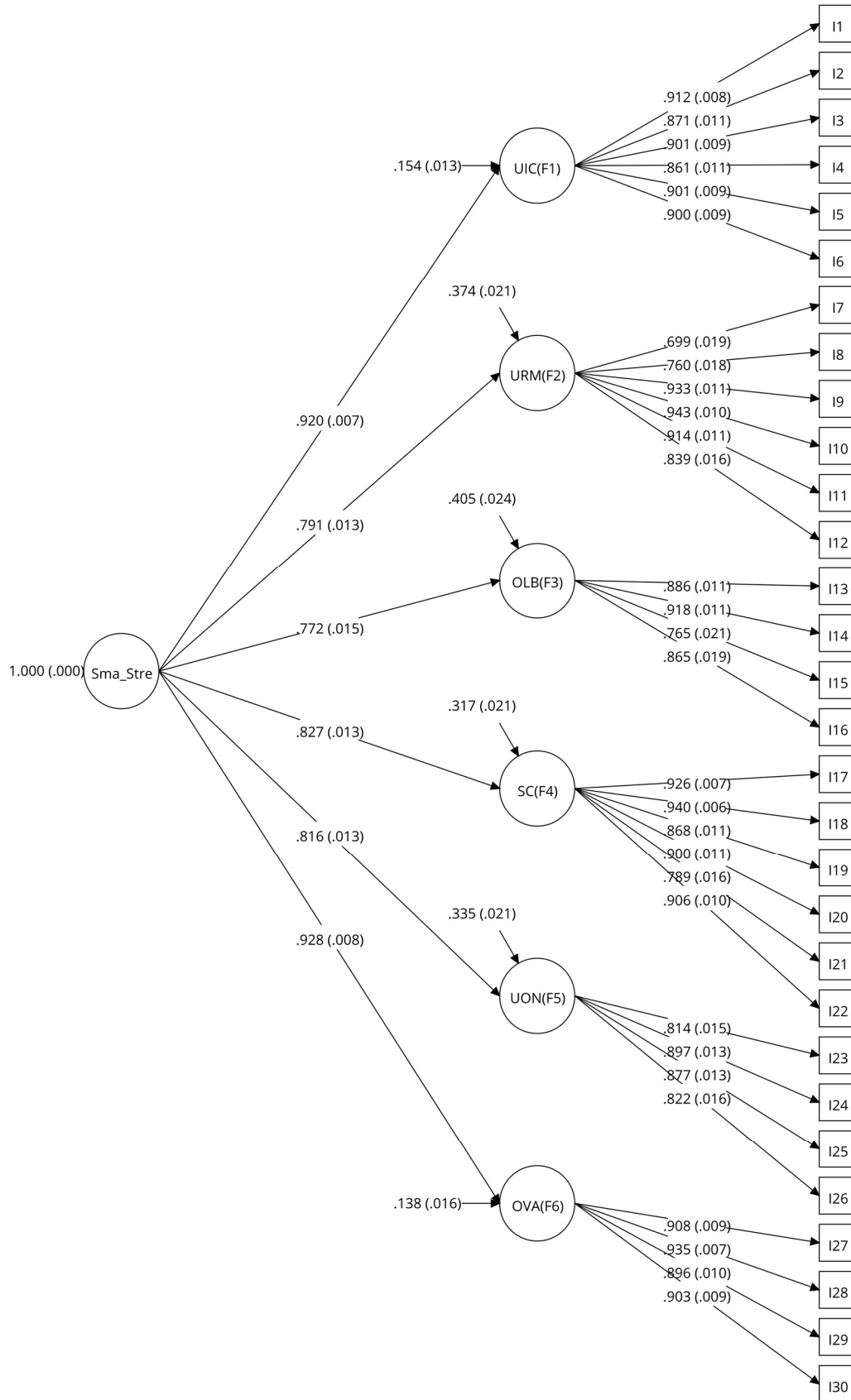
Note. F1 = Unsatisfactory information and communication (47% variance), F2 = Unmet recreational motivation (6.8% variance), F3 = Online learning burden (5.49% variance), F4 = Social concerns (5.29% variance), F5 = Useless and overloaded notifications (3.64% variance), F6 = Online verbal attacks (2.74% variance).

Figure A2. *Model Structure of the Short Smartphone Stress Scale.*
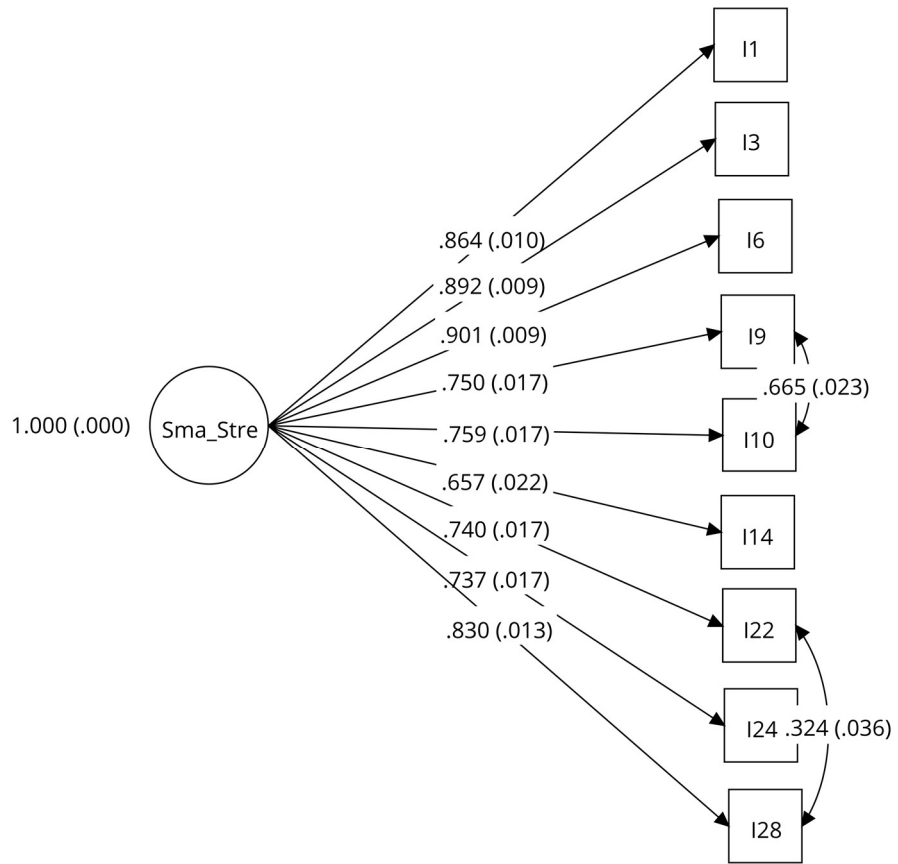
Supplementary Materials

中文版青少年手机压力量表

(Chinese Version of Smartphone Stress Scale for Adolescents）

指导语：使用手机的过程中人们可能会产生不太愉快的体验，如产生烦恼、焦躁等消极负面的情绪，或者感受到压力。以下题目列举了人们在使用手机的过程中通常会产生的消极情绪感受，请你评价自己在过去的一个月里，多大程度上经历过这些消极情绪感受。作答时不用考虑太多，请根据你的第一感受作答。

	从来没有	偶尔	经常	总是
1. 手机上沟通没法把事情说清楚让我感到难过	①	②	③	④
2. 输掉手机游戏中的比赛让我感到难过	①	②	③	④
3. 在手机新闻资讯中看到我所关心的人或事物的负面消息让我感到难过	①	②	③	④
4. 在手机短视频中看到我所关心的人或事物的负面消息让我感到难过	①	②	③	④
5. 浏览社交媒体时看到他人辱骂、攻击、恶意评论我关心的人让我感到难过†	①	②	③	④
6. 手机网课无法解决我的一些学习问题让我感到烦躁†	①	②	③	④
7. 手机搜索不到自己想要的信息让我感到焦虑	①	②	③	④
8. 手机搜索不到自己想要的信息让我感到难过†	①	②	③	④
9. 手机新闻资讯推送的广告让我感到生气†	①	②	③	④
10. 手机短视频评论区中的不良评论（如辱骂或攻击）让我感到生气†	①	②	③	④
11. 手机新闻资讯推送的广告让我感到厌烦	①	②	③	④
12. 手机上交流时他人的不良言语行为（如辱骂）让我感到厌恶	①	②	③	④
13. 手机搜索时出现许多无关信息让我感到厌烦	①	②	③	④
14. 玩手机游戏时队友的不配合行为让我感到愤怒†	①	②	③	④
15. 手机上沟通没法把事情说清楚让我感到烦躁	①	②	③	④
16. 手机短视频评论区中的不良评论（如辱骂或攻击）让我感到厌烦	①	②	③	④
17. 浏览社交媒体时看到我关心的人的负面消息让我感到难过	①	②	③	④
18. 玩手机游戏过程中被打断让我感到烦躁	①	②	③	④
19. 手机网课无法解决我的一些学习问题让我感到沮丧	①	②	③	④
20. 手机上玩游戏时他人给我发消息或打电话让我感到厌烦	①	②	③	④
21. 在手机短视频中看到我所关心的人或事物的负面消息让我感到厌恶	①	②	③	④
22. 手机搜索到说法不一的内容让我感到烦躁†	①	②	③	④
23. 玩手机游戏时队友的不配合行为让我感到烦躁	①	②	③	④
24. 手机新闻资讯推送的信息过多让我感到厌烦	①	②	③	④

	从来没有	偶尔	经常	总是
25. 输掉手机游戏中的比赛让我感到生气†	①	②	③	④
26. 在手机短视频中看到我所关心的人或事物的负面消息让我感到焦虑	①	②	③	④
27. 手机上交流时他人的不良言语行为（如辱骂）让我感到生气	①	②	③	④
28. 需要大量时间完成手机网课让我感到生气	①	②	③	④
29. 手机上沟通没法把事情说清楚让我感到焦虑†	①	②	③	④
30. 需要使用手机完成繁琐或复杂的作业使我感到厌烦	①	②	③	④

记分规则：

未满足的信息和交流(F1)：   1+7+8+15+22+29

未满足的娱乐动机(F2)：   2+14+18+20+23+25

网上学业负担(F3)：   6+19+28+30

社会关注(F4):   3+4+5+17+21+26

无用/过载信息(F5)：   9+11+13+24

网络言语攻击(F6)：   10+12+16+27

总分= F1+F2+F3+F4+F5+F6

得分越高表明手机压力水平越高

Smartphone Stress Scale for Adolescents

(Translated from Chinses to English）

Instruction: People may have unpleasant experiences when using mobile phones, such as developing negative emotions (e.g., worries, anxiety) or feeling stressed. The following questions list the negative emotions that people usually experience when using mobile phones. Choose the number that best fits your situation and tick it. Choose only one option for each question. You do not need to think too much when answering, please choose your answer based on your first feelings.

	Never	**Occasionally**	**Frequently**	**Always**
1. It makes me sad that I cannot communicate clearly on my smartphone	①	②	③	④
2. Losing mobile games makes me sad	①	②	③	④
3. Seeing negative news about someone or something I care about in my mobile news feeds makes me sad	①	②	③	④
4. Seeing negative news about someone or something I care about in a short video on my smartphone makes me sad	①	②	③	④
5. It makes me feel sad to see others insult, attack, or make mean comments about people I care about while browsing social media †	①	②	③	④
6. Online classes' failure to solve my study problems on the smartphone platform irritates me †	①	②	③	④
7. I feel anxious when I cannot find the information I want on my smartphone	①	②	③	④
8. I feel sad that I cannot find the information I want through my smartphone †	①	②	③	④
9. The advertisements pushed to my mobile news feeds make me angry †	①	②	③	④
10. Bad comments (e.g., abusive or offensive comments) in the comments section of short videos on my phone make me angry †	①	②	③	④
11. The advertisements pushed by my mobile news feeds irritate me	①	②	③	④
12. Bad verbal behaviors (e.g., abusive comments) when communicating on mobile phone make me feel disgusted	①	②	③	④
13. I am fed up with the large amount of irrelevant information that appears when I search on my phone	①	②	③	④
14. I feel angry when my teammates do not cooperate while playing mobile games †	①	②	③	④
15. I feel irritated when I cannot communicate clearly on my smartphone	①	②	③	④

	Never	Occasionally	Frequently	Always
16. I am sick of the malicious comments (e.g., abusive or offensive comments) in the comments section of short clips on my phone	①	②	③	④
17. Seeing negative news about someone I care about while browsing social media on smartphones makes me sad	①	②	③	④
18. Being interrupted while playing mobile games makes me feel irritated	①	②	③	④
19. Online classes' failure to solve my study problems on the smartphone platform frustrates me	①	②	③	④
20. People messaging or calling me while I play games on smartphone irritates me	①	②	③	④
21. Seeing negative news about someone or something I care about in a short video on smartphone makes me feel disgusted	①	②	③	④
22. I feel irritated when I search out inconsistent content on my smartphone †	①	②	③	④
23. The uncooperative behavior of teammates in mobile games makes me irritated	①	②	③	④
24. I am tired of the huge amount of information pushed to my mobile news feeds	①	②	③	④
25. Losing mobile games makes me angry †	①	②	③	④
26. Seeing negative news about someone or something I care about in a short video on my smartphone makes me feel anxious	①	②	③	④
27. I am offended by the people's bad language and behaviors (e.g., verbal abuse) when communicating on a mobile phone	①	②	③	④
28. I am angry at spending enormous amount of time to complete online classes on my smartphone	①	②	③	④
29. Being unable to communicate clearly on my smartphone makes me anxious †	①	②	③	④
30. I feel irritated when using my smartphone to complete complicated assignments	①	②	③	④

Note. † Items from the short version scale.

Score rule:
Unsatisfactory information and communication (F1): 1+7+8+15+22+29
Unmet recreational motivation (F2): 2+14+18+20+23+25
Online learning burden (F3): 6+19+28+30
Social concerns (F4): 3+4+5+17+21+26
Useless and overloaded notifications (F5): 9+11+13+24
Online verbal attacks (F6): 10+12+16+27
Total score = F1+F2+F3+F4+F5+F6.
Higher total score means higher level of smartphone stress.

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