

Running Head: DIGITAL STRESS MEDIATION

Digital Stress as a Mediator of the Relationship between Mobile and Social Media Use and  
Psychological Functioning

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We confirm that this study design, including research questions, hypotheses, variables and measures, was preregistered prior to conducting all analyses reported in the present investigation. This study was preregistered prior to the data collection of the adolescent sample but after collection of the young adult sample. We report where this manuscript conforms to the pre-registered plan and any places where there were changes to this plan are stated in the manuscript. All analyses performed in this manuscript were pre-registered. No post hoc or exploratory analyses were conducted, except a post hoc power analyses reflecting the final sample size.

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### Abstract

The present investigation uses Apple iPhone Screen Time to assess the association between mobile and social media use and psychological functioning with digital stress as a mediator in a sample of young adult ( $N = 267$ ) and adolescent ( $N = 213$ ) participants. The results of preregistered hypotheses suggest that as a five-factor composite (i.e., connection overload, approval anxiety, fear of missing out, availability stress, online vigilance) digital stress does not mediate the primary association. Connection overload, however, was a mediator of this relationship for all participants. Conditional process analyses revealed that for adolescents, FoMO and approval anxiety also mediated the primary association, but these digital stress subfactors were not mediators for young adult participants. Additionally, for young adults, mobile and social media use was associated with more positive peer relationships. The results suggest digital stress is closely tied to individuals' social environment and peer-related sources of stress.

**Keywords:** adolescents, anxiety, depression, digital stress, mobile media, social media, stress, young adults

## **Digital Stress as a Mediator of the Relationship between Mobile and Social Media Use and Psychological Functioning**

Although there has been considerable public and academic attention paid to the role of mobile and social media use on psychological functioning, there is a lack of evidence for a causal association between social media use and negative psychological outcomes (for review Hall, 2020). While a weak association has been detected in meta-analyses (Hancock et al., 2019; Huang, 2017), conceptual reviews suggest intervening variables may better explain this association (Baker & Algorta, 2016; Meier & Reinecke, 2020; Nesi et al., 2018). One such mediator is digital stress (Hefner & Vorderer, 2017; Reinecke, 2017).

Steele et al. (2020) defined digital stress as “the stress and anxiety that accompanies notifications from and use of informational and communication technologies enabled through mobile and social media” (p. 16). Drawing from past conceptualizations (e.g., Hefner & Vorderer, 2017; Nesi et al., 2018) and empirical research (LaRose et al., 2014; Reinecke et al., 2016), Steele et al. (2020) proposed that digital stress mediates the relationship between mobile and social media use and psychological functioning. Subsequently, Hall et al. (in press) developed candidate items and confirmed five factors of digital stress (i.e., connection overload, fear of missing out (FoMO), availability stress, approval anxiety, online vigilance). Reviewing the various conceptualizations of digital stress, Steele et al. (2020) and Hall et al. (in press) suggest that a mediated relationship between mobile and social media use and psychological functioning has both theoretical and empirical support.

The present investigation reports formal tests of the proposed mediation between mobile and social media use and psychological functioning (i.e., depression, anxiety, stress, social relationships) using the newly developed Digital Stress Scale (DSS) (Hall et al., in press). The

data collection procedures, study aims, measurement, and analysis methods of this study were [preregistered](#) prior to data analysis for both samples and prior to data collection for the adolescent sample. To address prior literature's reliance upon self-reported measures of mobile and social media use (Meier & Reinecke, 2020), the present study uses an objective measure of mobile and social media available from the iPhone's Screen Time application. The final sample included young adults ( $N = 267$ ) and adolescents ( $N = 213$ ) to examine whether the mediation model was conditional upon age of participant. The present investigation contributes to the existing literature by exploring under what conditions and for whom social and mobile media use is associated with negative psychological functioning.

### **Digital Stress**

The idea that some individuals respond negatively to or cope poorly with new technology is at least 40 years old (Brod, 1984). The concept has gone by many names, but recently the appellation of "digital stress" has gained traction (Hefner & Vorderer, 2017; Reinecke, 2017). Steele et al. (2020) proposed that digital stress is the subjective physiological, affective, or behavioral responses to specific stimuli (e.g., notifications) or class of stimuli (i.e., digital media). Digital stress is not conceptualized as and should not be measured by media use or consumption, the number of or choice of social media platforms or smartphone apps, or frequency of use. Importantly, digital stress is distinct from internet or social media "addiction," a concept with significant tautological problems conceptionally as well as measurement comorbidities (Meier et al., 2020). Instead, consistent with the historical origins of the concept (Brod, 1984), responses to digital media vary based upon each person's available coping resources. For example, the same number of digital messages or notifications may be stressful to one individual but not for another (Hefner & Vorderer, 2017). Furthermore, individual

differences in digital stress should be understood in relation to the social environment of the media use (Meier et al., 2020; Nesi et al., 2018). Indeed, communication with friends and family is the most common reason for mobile and social media use (Hall, 2020). Consistent with this theoretical foundation, both subjective and relational considerations were taken into account in the development of the DSS (Hall et al., in press).

Steele et al. (2020) proposed and Hall et al. (in press) developed and validated the factorial structure of digital stress. Steele et al. (2020) proposed four factors: *availability stress*, which is the “distress (including guilt and anxiety) resulting from beliefs about others’ expectations that the individual respond and be available by digital means” (p. 18); *approval anxiety*, which is the “uncertainty and anxiety about others’ responses and reactions to one’s posts or to elements of one’s digital footprint” (p. 19); *fear of missing out*, which is “distress resulting from the real, perceived, or anticipated social consequences of others engaging in rewarding experiences from which one is absent” (p. 19); and *connection overload*, which is the “distress resulting from the subjective experience of receiving excessive input from digital sources, including notifications, text messages, posts, etc.” (p. 20). Based upon the empirical evidence, Hall et al. (in press) identified a fifth factor, identified as *online vigilance* given the concept’s similarity to Reinecke et al.’s (2018) measure of online vigilance that was developed concurrently but independently of the DSS. Reinecke et al. (2018) define online vigilance as “... users’ permanent awareness of the availability and goal-serving potential of mobile online services and communication as well as their motivational disposition to exploit these options anywhere, anytime, and with regard to (virtually) any situational circumstance” (p. 5). For a review of quantitative research on digital stress, see Table 1.

[Table 1 about here]

### **The Mediation Model**

At its core, mobile devices are conduits of information and most of that information is social in nature. Social media platforms (e.g., Facebook, Instagram, WhatsApp) aggregate social information from user-selected networks of friends, followers, and contacts. Mobile devices have increasingly supplanted desktop and laptop computers as the primary point of access to social media (Jiang, 2018). For many, the functions of mobile phones (e.g., texting) and affordances of social media (e.g., scrolling the newsfeed) have coalesced into a single point of access – the smartphone – which most individuals keep on hand constantly (Jiang, 2018).

There are two broad dimensions of digital stress: one is technological in nature (i.e., connection overload, online vigilance) and the other is social in nature (i.e., availability stress, approval anxiety, FoMO) (Hall et al., in press; Steele et al., 2020). Both, however, are brought into users' awareness through the social information flowing through their mobile devices. Past conceptualizations of digital stress (Hefner & Vorderer, 2017) concur that psychological responses arising from entertainment content, gaming, and news media are beyond the scope of the digital stress concept. The present investigation adopts a similar position; digital stress is a product of the technological and social context users are situated in, not an all-encompassing measure of responses to media content in all its forms.

The social experience of mobile and social media offers both benefits and drawbacks (Baker & Algorta, 2016; Hall, 2020; Hancock et al., 2019). Mobile and social media offer users the opportunity to connect with friends and followers geographically near and far, reducing energy costs of maintaining contact while increasing access to possible relationship partners. Users may experience an excess of connectivity when the number of photos, messages, and notifications place unwanted demands on users' time and attention (LaRose et al., 2014; Thomée

et al., 2010). This duality of connectivity and connection is at the core of both technological and social components of digital stress (Hall, 2020; Steele et al., 2020). The information flowing through a mobile device can be thought of bringing about the experience of connection overload and online vigilance; as notifications, pick-ups, and social media use rise, feelings of digital stress likely increase in kind.

On the social connection side of digital stress lies availability stress, approval anxiety, and FoMO. In connecting through technology with peers far and wide, individuals must navigate peer expectations of availability and responsiveness, which may result in availability stress. A similar concept is entrapment, which encompasses feelings of guilt, anxiety, and stress felt in response to the expectation to be constantly available and responsive to texts, notifications, and shared content (Hall 2017; Hall & Baym, 2012). Availability stress can be thought of the internalization of expectations of availability to peers through mobile devices. Availability stress is associated with the frequency of mobile relationship maintenance (Hall & Baym, 2012) and the number of unique relational partners maintained through mobile devices (Hall, 2017).

Approval anxiety and FoMO originate from how others regard and the degree to which they include the user, as made evident by others' digital media content and others' responses to the user (Nesi et al., 2018; Steele et al., 2020). Mobile and social media offer users a variety of ways to engage in self-presentation and satisfy various social needs, including the need to feel included and well regarded (Beyens et al., 2016; Baker & Algorta, 2016; Morin-Major et al., 2016). Social media platforms, particularly ones that focus on photo displays, require intentional self-presentation if users wish to share content on the platform (Hall, 2020). This may steer users toward social comparison, wherein individuals compare themselves (or their digital images) to that of friends (Feinsten et al., 2013; Sabik et al., 2020; Steers et al., 2014). Similarly, FoMO

involves being made aware of, sometimes inadvertently, of photos or updates that inform the user that friends are enjoying themselves and the host of negative emotions (e.g., envy, anxiety, jealousy) that arise from this awareness (Pryzbylski et al., 2013; Reinecke et al., 2016).

### **Developmental Argument**

There is reason to believe that the experience of digital stress may have a differential influence on adolescents compared to young adults. Feeling left out and excluded has been highlighted as a particularly difficult experience for adolescents, given the emphasis on peer affiliation occurring at this stage of life (Barry et al., 2017; Beyens et al., 2016). Thus, the conduit of social information brought about by mobile and social media increases exposure to and awareness of peer (dis)approval as well as a variety of peer experiences and impressions. As Nesi et al. (2018) argue, much of adolescent life is *lived in* mobile and social media. Therefore, the photos, posts, and messages accessed through mobile devices are constitutive, rather than merely reflective, of relationships between peers. Consequently, adolescents may be influenced by the social aspects of digital stress at rates greater than those of young adults.

### **Preregistered hypotheses and research questions**

The present investigation was [preregistered](#) along with four hypotheses:

H1: Smartphone and social media weekly use will be negatively associated with psychological functioning (e.g., perceived stress, loneliness, depressive symptoms, anxiety).

H2: Smartphone and social media weekly use will be positively associated with digital stress.

H3: Digital stress will be positively associated with psychological functioning (e.g., perceived stress, loneliness, depressive symptoms, anxiety).



H4: The association between smartphone and social media weekly use and psychological functioning will be mediated by digital stress.

The preregistration included two secondary analyses, presented here as two RQs:

RQ1: Will the specific sub-components of digital stress offer a better fit to the data when testing the mediation model, compared to a single higher-order latent model?

RQ2: Will the patterns of hypothesized associations vary by age group (i.e., adolescent vs. young adults)?

## METHOD

The participant recruitment plan and study measures were preregistered. All study methods followed preregistered methods and analyses unless otherwise noted. The methods of the first sample received IRB approval 06/24/19, and the data were collected from 09/19/19 to 10/31/19. The methods for the second sample receive IRB approval 11/12/19, and the data collection time frame was 2/10/20 to 9/2/20.

### **Objective Measures of Mobile and Social Media**

One of the most important areas of development in research on mobile and social media is moving beyond self-reported indicators of use and toward objectively measured use (Dienlin & Johannes, 2020; Griffioen et al., 2020; Meier & Reinecke, 2020). Scoping reviews confirm that only 6% of extant research has employed an objective measure (Griffioen et al., 2020), and a considerable portion of that small percentage were studies written by researchers from social media companies who have exclusive access to user data (e.g., Burke & Kraut, 2016). Part of the challenge is that objective measures built into common devices (e.g., mobile devices) or platforms (e.g., Facebook) were simply unavailable to researchers until fairly recently (Griffioen et al., 2020). Meier and Reinecke (2020) write, “Studies should strive to measure technology use

descriptively, ideally via digital tracking” (p. 6). One recommended form of digital tracking is Apple’s iPhone Screen Time program (Ernala et al., 2020; Meier & Reinecke, 2020). Screen Time maintains a record of social media apps usage, notifications, and pick-ups – the latter two are particularly challenging to self-report (Dienlin & Johannes, 2020). The present study adopts these recommendations by using Screen Time for measures of use.

### **Participants and procedures sample one: Young adults**

*Procedures.* College student participants were recruited from communication and psychology courses at study authors’ university. Students were considered eligible if they were between the ages of 18 and 23, reported use of an Apple iPhone and the use of digital communication, and provided informed consent. Participants were offered either extra credit or partial course credit in exchange for participation. Interested students who met study criteria signed up to attend one 25-minute data collection session in groups of 3-20 participants. Data were collected via paper-and-pencil measures by trained research assistants under the supervision of graduate research assistants.

After completing the questionnaires, participants were informed of the option of reporting objective mobile use data. If participants provided consent, they were instructed to open the Screen Time option on their iPhone and pass it to the research assistants and the graduate study coordinator to view and record independently. Thus, data were double entered and confirmed at the time of collection by both research assistants. Data entered was total time on social media platforms (e.g., iMessage, Instagram, Snapchat, Facebook, Twitter, Facebook Messenger), total number of pick-ups (each time the phone was picked up), and total number of notifications received from any application on the iPhone. Consistent with the preregistered exclusion criteria, participants who refused to share iPhone data or did not enable Screen Time were not included.

Participants ( $N = 267$ ) reporting sex were 66.1% female, and no participants were trans-identifying or non-binary. Participants were an average of 18.7 years of age (range 18-23, mode = 18). Participants were asked to identify as many race/ethnicity categories as they wanted: 80.9% identified as white, 4.9% as Black or African American, 7.5% Hispanic/Latinx, 6.8% Asian American, 3.4% Chinese national, 3.4% South Asian national, and 1.1% Native American, and 1% as some other race.

### **Participants and procedures sample two: Adolescents**

*Procedures.* Adolescent participants were recruited using Qualtrics™, a secure online panel and survey-technology provider to recruit a nationally-representative sample of adolescents. Participants were eligible if they were between ages 14 and 17, used an Apple iPhone, used social media, and were able to read and respond to self-report questionnaires in English. Parents of eligible participants were provided with an electronic consent form with information about the study. Once parents provided informed consent electronically, they were given a link to the survey to share with their adolescent. Adolescents were then able to provide assent and complete the survey. Participants were reimbursed for participation through Qualtrics. Surveys responses were checked by lab members to assess for entries with low response variability or low survey completion time. Data responses that were determined to be unusable were reported to Qualtrics and removed from the database.

Adolescents were instructed to take screen shots of their Screen Time settings to display social media use, notifications and pick-ups. They were instructed to upload the screenshots to Qualtrics. Uploaded screenshots were inspected by study team members for accuracy and authenticity. Screenshots were considered usable if at least one of the three values was correctly uploaded. For example, if a participant uploaded a screenshot of their social media time but did

not upload screenshots of notifications or pick-ups, it was considered usable. Screenshots were not considered usable if the pictures were fake, of non-Apple phones, or not uploaded. If participants had Screen Time off, they were instructed to include a screenshot as confirmation. Their data were not included, which was consistent with preregistered exclusion criteria.

Adolescent participants ( $N = 213$ ) reporting sex were 49.5% female and 49.5% male, and 1% identified as non-binary. Participants were an average of 15.3 years of age (range 14-17, mode = 14). Participants were asked to identify as many race/ethnicity categories as they wanted: 61.3% identified as white, 13.2% as Black or African American, 17.9% Hispanic/Latinx, 11.8% Asian American, and 2.4% Native American, .1% as Hawaiian and 1.9% as some other race.

### **Power analysis**

The pre-registered goal of participant recruitment ( $N = 615$ ) faced several barriers, including recruiting a sufficient number of adolescents via the Qualtrics panel during the COVID-19 pandemic. Although 642 participants were initially recruited, 36 college students did not have Screen Time enabled. An additional 126 participants from both samples (86% adolescents; 14% college students) did not provide any usable data from Screen Time. Combining both samples, the final sample size was 480 participants who provided at least one of the three objective measures of mobile and social media use.

As stated in the pre-registration, the ‘true’ associations between (a) mobile and social media use and digital stress and (b) between digital stress and psychological dysfunction were unknown prior to data collection because validated measures of digital stress had not yet been created. These data collection problems and unknown estimates made it necessary to conduct a post-hoc power analysis with the final sample. With sample size of 432 (the lowest  $n$  with usable objective use data), this study is able to detect an effect size of  $r = .185$  with a power of .90 and

an alpha risk level of .01.

## Measures

*Mobile & social media use.* Consistent with the preregistered measures, three measures of mobile and social media use were taken from iPhone Screen Time: *mean daily minutes of social media*,  $M = 137$ ,  $SD = 79$ ,  $n = 457$ ; *mean daily pick-ups*,  $M = 131$ ,  $SD = 73$ ,  $n = 432$ ; *mean daily notifications*,  $M = 210$ ,  $SD = 186$ ,  $n = 438$ .

Consistent with the preregistered aims of the study, the factor structure of digital stress based on the literature review and conceptual argument of Steele et al. (2020) was confirmed in Hall et al. (in press) for both young adult and adolescent samples. The five factors are *connection overload*, *availability stress*, *approval anxiety*, *FoMO*, and *online vigilance* (see below for confirmatory factor analyses (CFA)).

Consistent with the preregistered measures of psychological functioning, all participants completed the *perceived stress scale* (PSS; Cohen et al., 1983), a widely used psychological instrument used to assess generalized stress. All participants completed age-appropriate versions of the Patient-Reported Outcomes Measurement Information System (PROMIS) scales (Bevans et al., 2014). PROMIS is a set of person-centered measures developed by the National Institutes of Health that assess physical, mental, and social health in adults and adolescents (<http://nihpromis.org>). Young adult participants completed PROMIS scales of *companionship* (six items with higher scores indicating a lack of loneliness), *anxiety*, (eight items) and *depressive symptoms* (eight items). Adolescents completed age-appropriate measures from the adolescent PROMIS scale: *social relationships*, *anxiety*, and *depressive symptoms*. The companionship and social relationships measures were used to measure loneliness because

greater peer inclusion was theorized to be indicative of a lack of loneliness. Table 2 reports the correlations between all study variables.

[Table 2 about here]

## RESULTS

The preregistered proposal had two research aims. Hall et al. (in press) achieved the goals of aim one: To establish a reliable and valid measure of digital stress that demonstrated measurement invariance for adolescents and young adults. The present investigation used the DSS to answer the second aim: to empirically examine associations between objective measures of smartphone use, the five-factor model of DSS, and psychological functioning (e.g., perceived stress, depressive symptoms, anxiety, social functioning). All analyses reported here are unique to this manuscript.

### Measurement model for digital stress

Below are the results of a CFA of the DSS in MPLUS 7.13 (Muthen & Muthen, 2012-2015). All items loaded significantly on their respective latent factors, and the five-factor model was an acceptable fit to the data, RMSEA = .075 (90% CI of .070 to .081), CFI = .918, TLI = .906, SRMR = .079,  $\chi^2(242) = 900, p < .001$ . Hall et al. (in press) identified three items with similar stems and conceptualizations that improved model fit based on modification indices, but recommended that “future researchers using the DSS measure should confirm rather than assume that this modified model is the best fit to the data” (p. 10). The results of the modified model suggest a substantial improvement in model fit:  $df_{diff} = 3, \chi^2 = 311$ . Overall fit statistics for the revised measurement model showed an excellent fit to the data: RMSEA = .055 (90% CI .050 - .061), CFI = .956, TLI = .949, SRMR = .069,  $\chi^2(239) = 589, p < .001$ .

Finally, Hall et al. (in press) report that the higher order factor for DSS showed an excellent

fit to the data. The present investigation found that the measurement model including the higher order latent indicator of DSS was an excellent fit to the data: RMSEA = .058 (90% CI .053 - .064), CFI = .950, TLI = .944, SRMR = .074,  $\chi^2(244) = 640, p < .001$ . These analyses suggest that the DSS can either be empirically conceptualized as five separate subcomponents or as a single latent measure of digital stress with five sub-dimensions.

### **Confirmatory hypotheses**

The four preregistered confirmatory hypotheses made up a simple mediation model. Following all preregistered procedures, three higher-order latent variables for all three study concepts were created. Model fit indices suggested that the measure of loneliness/companionship was a poor fit to the psychological outcomes measure. Given that it was the only measure of positive functioning, the three measures of poor psychological functioning (i.e., depression, anxiety, stress) were analyzed separately from loneliness/companionship.

Structural equation modeling in MPLUS 7.13 was used with bootstrapped estimates of indirect effects, while participant age, sex (Female = 1, non-binary = 0, Male = -1), race (White = 1), ethnicity (Latinx = 1), and collection pre- or post-COVID-19 as covariates.<sup>1</sup> Showing no support for H1, the unstandardized path estimates indicated that smartphone and social media use was unrelated to psychological functioning,  $b = -.001, SE = .001, p = .387$ . Showing no support for H2, the unstandardized path estimates indicated that objectively measured smartphone and social media use was unrelated to digital stress,  $b = .001, SE = .001, p = .389$ . In support of H3, digital stress was strongly associated with poor psychological functioning,  $b = 1.082, SE = .123, p < .001$ . Finally, showing no support for H4, a Sobel test suggested the indirect association

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<sup>1</sup> Data for adolescents were both prior to and after the emergence of the COVID-19 pandemic (i.e., ~March 6, 2020), and the steps taken to protect population health (e.g., shelter in place orders). For the sake of controlling for unexplained variance due to the pandemic, a pre- and post- March 3 variable was created for the adolescent sample and was included as a covariate in SEM models.

between smartphone and social media use and psychological functioning was not mediated by digital stress,  $b = .001$ ,  $SE = .001$ ,  $p = .388$ . Thus, the mediation model using the composite DSS was not supported.

A similar model was estimated using social relationships as the dependent variable. Contradicting H1, the unstandardized path estimate indicated that smartphone and social media use was positively related to higher quality social relationships,  $b = .160$ ,  $SE = .041$ ,  $p < .001$ . Showing no support for H2, the unstandardized path estimate indicated that smartphone and social media use was unrelated to digital stress,  $b = .056$ ,  $SE = .060$ ,  $p = .347$ . In support of H3, digital stress was associated with poor social relationships,  $b = -.139$ ,  $SE = .037$ ,  $p < .001$ . Showing no support for H4, a Sobel test suggested the indirect association between smartphone use and social relationships was not mediated by digital stress,  $b = -.008$ ,  $SE = .009$ ,  $p = .367$ .

### **Preregistered secondary analysis**

To answer RQ1, a secondary mediation analysis explored whether associations varied by sub-component of digital stress. To accomplish this goal, modification indices were requested from the primary model. The modification indices suggested that the connection overload sub-factor of digital stress should be free to vary with measures of social and mobile media use.

The recommended model was supported: connection overload was a significant mediator of the association between media use and poor psychological function, and the model was an acceptable fit to the data: RMSEA = .080 (90% CI of .069 to .092), CFI = .939, TLI = .921, SRMR = .050,  $\chi^2(51) = 209$ ,  $p < .001$ . The unstandardized path estimates indicated that smartphone and social media use was unrelated to poor psychological functioning (H1),  $b = -.003$ ,  $SE = .001$ ,  $p = .059$ . The unstandardized path estimates indicated that smartphone and social media use were positively related to overload,  $b = .004$ ,  $SE = .001$ ,  $p = .002$ . In support of



H3, overload was positively associated with poor psychological functioning,  $b = .456$ ,  $SE = .058$ ,  $p < .001$ . Finally, a Sobel test suggested that the association between smartphone and social media use and psychological functioning was mediated by connection overload,  $b = .002$ ,  $SE = .001$ ,  $p = .004$  (see Figure 1).

Modification indices were also consulted when social relationships served as the dependent variable. Indices suggested that FoMO and approval stress should be free to vary with social relationships, however, neither was associated with mobile and social media use.

### **Preregistered conditional analyses**

A moderation analysis by age group (RQ2) was conducted on the primary model, the model with social relationships, and in the secondary model with individual digital stress sub-factors (i.e., a total of seven mediation models). The results of the conditional mediation model for the primary model (i.e., the five-factor digital stress measure) suggested that age was not a moderator. Furthermore, the results of the conditional mediation model using social relationships as the dependent variable suggested that age was not a moderator.

The secondary mediation models with five digital stress sub-factors were then tested to determine if age moderated individual digital stress factors. To probe significant moderations, the PROCESS macro (Hayes, 2018) was used to identify for regions of significance using the pick-a-point technique (i.e., the conditional indirect effects of mobile and social media use on psychological functioning at 14<sup>th</sup>, 50<sup>th</sup>, and 84<sup>th</sup> percentiles).

Across all five models, the direct effect ( $c'$ ) was moderated by age. Specifically, more mobile and social media use was positively associated with poor psychological functioning for participants 16 years and younger, but for older participants (22 & 23 years of age) it was associated with positive psychological functioning. A similar pattern of results was detected

when social relationships was the dependent variable: for participants 16 years and older, more mobile and social media use was positively associated with reporting higher quality social relationship, but for younger participants that association was not significant.

Three of the five moderated mediation models failed to detect a significant moderation by age. For the model testing FoMO, however, there was a significant moderation by age for the path between mobile and social media use and FoMO,  $b = -.092$ ,  $SE = .032$ ,  $p = .004$ ,  $R^2\Delta = .02$ . Using 5,000 bootstrapped estimates to probe this interaction, the results suggested that FoMO moderated the association between social media use and poor psychological functioning for participants 15 years of age,  $b = .115$ ,  $SE = .040$ ,  $LLCI = .031$ ,  $ULCI = .188$ , but not for participants 18 and older,  $b = -.015$ ,  $SE = .038$ ,  $LLCI = -.062$ ,  $ULCI = .036$ .

The model for approval anxiety showed a significant moderation by age for the path between use and approval anxiety,  $b = -.088$ ,  $SE = .034$ ,  $p = .009$ ,  $R^2\Delta = .014$ . Using 5,000 bootstrapped estimates to probe this interaction, the results suggested that approval anxiety mediated the association between social media use and poor psychological functioning for participants 15 years of age and younger,  $b = .090$ ,  $SE = .036$ ,  $LLCI = .015$ ,  $ULCI = .158$ , but not for participants 18 and older,  $b = -.033$ ,  $SE = .027$ ,  $LLCI = -.090$ ,  $ULCI = .017$ .

## DISCUSSION

The present investigation is the first to use data from Apple iPhone Screen Time to assess the association between mobile and social media use and psychological functioning, the first to test the five factors of DSS (Hall et al., in press) as a mediator of that relationship, and the first to preregister these hypotheses prior to data collection (i.e., adolescent sample) and analysis (i.e., college and adolescent sample). In response the first preregistered research aim, the results suggest that, as a five-factor composite, digital stress does not mediate the mobile and social

media use and psychological functioning relationship. In response to the secondary research aim, however, connection overload mediated this relationship for all participants. Furthermore, conditional process analyses revealed that for adolescents, FoMO and approval anxiety mediated the mobile and social media use and psychological functioning relationship. Therefore, although digital stress as a five-factor model does not serve as a uniform mediator, individual DSS subfactors may explain the association between mobile and social media use and psychological functioning. Below we discuss these results in light of prior research and theory.

### **Connection Overload**

The conceptual definition of connection overload provided by Steele et al. (2020, p. 20) (i.e., “distress resulting from the subjective experience of receiving excessive input from digital sources, including notifications, text messages, posts”) is notably consistent with the operationalization of mobile and social media in the present investigation. Each of the three types of mobile and social media use captured by Screen Time (i.e., social media time, pick-up frequency, notification frequency) were sources of digital input. Additionally, these objective measures, whether taken as a whole or individually, significantly covaried with participants’ subjective experience of connection overload. This subfactor was conceptualized as arising from the device itself and the functions enabled on it, rather from relationships with communication partners (Hall et al., in press; Steele et al., 2020). Thus, it stands to reason that mobile and social media use, measured objectively through Apple’s Screen Time, gives rise to a feeling of being overwhelmed, which in turn contributes to poor psychological functioning. Past research supports connection overload as a salient mediator, most notably Primack et al. (2017) who showed a greater number of social media accounts/platforms was associated with markers of depression and anxiety. Consider that participants who were one standard deviation above mean

levels of digital media use would engage in 3.5 hours of social media use, over 200 pick-ups, and nearly 400 notifications *each day*. Such numbers put into perspective the degree of digital load experienced by adolescents and young adults at the high end of mobile and social media use.

Somewhat unexpectedly, however, mobile and social media use was also associated with having more supportive and inclusive peer relationships, but digital stress was consistently associated with lower quality peer relationships (as well as higher stress, anxiety, and depression). For decades, the relationship between mobile media use and social well-being has been viewed as a duality (Arnold, 2003; Hall & Baym, 2012). Having many peers to keep in touch with through one's mobile device leads to many more texts and notifications (Hall, 2017). Yet, this permanently online condition (Reinecke, 2017) appears to contribute to a feeling of being overwhelmed and overloaded, which in turn results in enhanced stress and anxiety. In the present study, mobile and social media use contributed to negative outcomes via connection overload, yet it was *also* the case that mobile and social media was associated with social cohesion and inclusion. The feeling of being overwhelmed may, in fact, be associated with both desirable outcomes, such as having friends and being included, as well as undesirable outcomes, such as the anxiety and stress resulting from having too many messages, pictures, memes, and notifications to attend to (Dissing et al., 2020; Lo, 2019; Reinecke, 2017). Despite being overloaded by social and mobile media, peer connection mitigates negative effects of social media use (i.e., SNS exhaustion) and enhances positive effects of social media use (i.e., SNS satisfaction) (Lo, 2019). These results represent an underlying tension of the permanently online, permanently connected experience; enhanced connectivity with peers, potentially at the expense of well-being.

Although availability stress, or social pressure to respond to messages from others, did not show a mediating relationship in the present investigation, Hall et al. (in press) report that the subfactor was associated with greater companionship for adults. In the present study, availability stress was weakly associated with all three Screen Time measures, and significantly associated with pick-ups for college students and greater peer support and inclusion in general. Past research has suggested that internalized social pressure to be available to friends arises as a result of technological notifications and mobile device awareness, it does not satisfy individuals' needs for social connection (Halfmann & Rieger, 2019). Thus, the subjective experience of social pressure is weakly related to both digital media use and having more peers, but, in itself, availability stress is not particularly stressful or a particularly good indicator of getting social needs met. Perhaps these effects, if present, are particularly small and may require a large sample size to detect. Mai et al. (2015) offers another possible explanation for observed results; the perceived expectation to be available may be inaccurate; individual perceived a higher degree of online responsiveness than their conversational partners actually expect. That is, the pressure to be available is possibly perpetuated by the individual's perceptions of accessibility, as opposed to actual peer expectations.

### **Moderated mediation by age**

Two of the five mediation models were moderated by participant age: FoMO and approval anxiety. In both cases, younger adolescents (i.e., 14-16-year-olds) were more likely than young adults (18+) to report heightened FoMO and approval anxiety when their mobile and social media use increased. For young adults, the relationship between digital media use and these forms of digital stress was not present. Interestingly, adolescents did not show a stronger association between digital stress (i.e., FoMO, approval anxiety) and psychological functioning

(i.e., stress, anxiety, depression) in comparison to young adults (Table 2). Instead, their patterns of mobile and social media use explained more variance in digital stress than for young adults.

Theoretically, however, there is reason to believe that these two digital stress factors – peer approval and FoMO – are more acute for adolescents. Several researchers (e.g., Barry et al., 2017; Beyens et al., 2016; Nesi et al., 2018) have suggested that the developmental challenges associated with adolescence may render them more susceptible to stressors arising from troubled or inconstant peer relationships. As Steele et al. (2020) suggested in their conceptual model, FoMO and approval anxiety arise from a similar source of information: the absence of inclusion from one's peers brought to attention by mobile and social media. The present study supports the argument that feeling excluded by peers is a particularly difficult experience for adolescents, perhaps leaving them more vulnerable to negative social cues they discover when using mobile and social media (Nesi et al., 2018).

Finally, it is notable that of the five forms of digital stress, FoMO was the strongest predictor of both poor psychological functioning and less peer support and inclusion, supporting prior research (see Table 1). Yet, FoMO shows neither a strong nor a consistent association with the three objective measures of digital media use gathered by Screen Time. Rather, the present study suggests more social networking, notifications, and pick-ups are associated with higher quality peer relationships. One possible interpretation of the results of the present study is that FoMO is a good predictor of poor outcomes, but it does not arise from digital media use. Rather, heightened FoMO may be due to experiencing chronic feelings of exclusion – both offline and online (see Barry et al., 2017). Beyens et al. (2016) suggested that social needs (i.e., need to belong) result in FoMO, which serves as the impetus for more Facebook use (Beyens et al., 2016). Thus, FoMO may be a predictor of social media use as adolescents try to satisfy social

needs as well as a moderator of how adolescents interpret information they find there. Mobile and social media are conduits by which adolescents perceive exclusion. Online photos, updates, and messages are not necessarily directed at the person experiencing FoMO, but are interpreted by them as such. This is consistent with this study's findings that participants who have better peer relationships, not participants with greater FoMO, use social and digital media more.

### **Limitations**

The present study used high-quality measures for all three of the primary variables of interest (i.e., media use, digital stress, psychological functioning), following best practices (Ernala et al., 2020; Meier & Reinecke, 2020). This study engaged in preregistration, a recommended research practice. Nonetheless, its methods are not without limits. Specifically, this study did not manipulate social and mobile media use. Thus, the presumption of causality or causal order cannot be assumed. Although efforts were made to gather a diverse and representative adolescent sample, the present study is limited by its use of two convenience samples. The results of the present investigation should not be assumed to be generalizable to all adolescents or young adults. Although sex, race, and ethnicity were controlled for to account for differences between samples, the data collection mode and the geographic distribution of the college and adolescent samples were distinct. Furthermore, adolescent data were partly collected during the COVID-19 pandemic, which may have created a confound when comparing the two groups. This variance was accounted for by statistically controlling for pre- and post-COVID data collection times. Nonetheless, it is possible that uncontrolled differences between the samples accounted for different results that were attributed to age group.

Although two of the three measures used in the present study (i.e., notifications, pickups) were content free, the measure of social media use could not discern the content of the

information received. Because the social media minutes measure of Screen Time combined iMessage and Facebook direct messaging with passive scrolling on Instagram and Twitter, for example, it could not disentangle active and passive forms of social media use, which may be a notable moderator of the digital media use to well-being association (Hancock et al., 2019).

Future research may try to combine the amount of media use, the content of messages, its source, and its valence using methods that combine objective and subjective measures, such as experience sampling with in-the-moment objective data gathering (Dienlin & Johannes, 2020).

### **Conclusions**

One of the strongest conclusions of the present study is mobile and social media use must be interpreted in relation to the peer environment of adolescents and young adults. Rather than a simple force for ill or gain, mobile and social media use appears to reflect the social environment and available coping resources of young people. As Arnold (2003) foretold, it is Janus-faced: the very messages, notifications, and pick-ups that allow the user to enjoy a meme, a message, or photo sent from friends appears to contribute to a sense of being overwhelmed and exhausted by the sheer volume of information. For adolescents particularly, exposure to more social media content may make salient feelings of judgment and exclusion, contributing to negative outcomes. Yet, as they mature into young adults, the salience of those stressors may recede, and patterns of mobile and social media use may begin to reflect the presence of a healthy social and psychological social system.



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Table 1

*Review of Quantitative Empirical Findings by the Five Digital Stress Factors*

<b>Quantitative Study</b>	<b>Digital Stress</b>	<b>Findings</b>
Feinstein et al., 2013	Approval Anxiety	Negative social comparison on Facebook predicted depressive symptoms through increased rumination.
Nesi & Prinstein, 2015	Approval Anxiety	Online social comparison related to depression, especially for low popularity and female adolescents
Steers et al., 2014	Approval Anxiety	Approval anxiety (social comparison) mediated the relationship between Facebook use and depressive symptoms
Halfmann & Reiger, 2019	Availability Stress	Availability stress unassociated with relatedness needs, but was associated with self-control failure
Hall, 2017	Availability Stress	Entrapment (availability stress) mediates negative association between texting and well-being cross sectionally and over a week
Mai et al., 2015	Availability Stress	Availability stress (when friends were unresponsive to texts) associated with fear of ostracism and negative affect
Chen & Lee, 2013	Connection Overload	Communication overload mediated the relationship between Facebook interaction and distress: Communication overload was directly associated with distress, and indirectly associated with distress through lower self-esteem
La Rose et al., 2014	Connection Overload	Connection overload mediated digital media use and well-being relationship
Morin-Major et al., 2016	Connection Overload	Facebook social network size and peer interactions associated with stress cortisol
Primack et al., 2017	Connection Overload	Using more social media platforms associated with depression and anxiety
Reinecke et al., 2016	Connection Overload	Connection overload negatively associated with perceived stress. Communication load indirectly predicted depression and anxiety through burnout for older adults
Misra & Stokols, 2012	Connection Overload	Overload predicted increase in stress and decrease in health over time
Thomé et al., 2010	Connection Overload, Availability Stress	Connection overload or availability stress associated with negative mental health
Barry & Wong, 2020	FoMO	FoMO associated with low self-esteem and loneliness, more social media use
Barry et al., 2017	FoMO	There was a moderation effect between social media, FoMO, and anxiety/depression. More social media use and higher reports of FoMO predict increased anxiety and depression for adolescents
Beyens et al., 2016	FoMO	FoMO mediates association between Facebook-associated stress and unmet belongingness needs for adolescents
Blackwell et al., 2017	FoMO	FoMO significantly predicted social media use and addiction, exceeding all other predictors
Reer et al., 2019	FoMO	Social comparison and FoMO mediated the relationship between psychosocial well-being and social media engagement
Johannes et al., 2020	Online vigilance	Online vigilance only weakly associated with well-being
Wolfers et al., 2020	Online vigilance	Nomophobia (fear of being without mobile device) associated with stress



Table 2  
*Correlation Matrix Adolescents (above diagonal) & College students (below diagonal)*

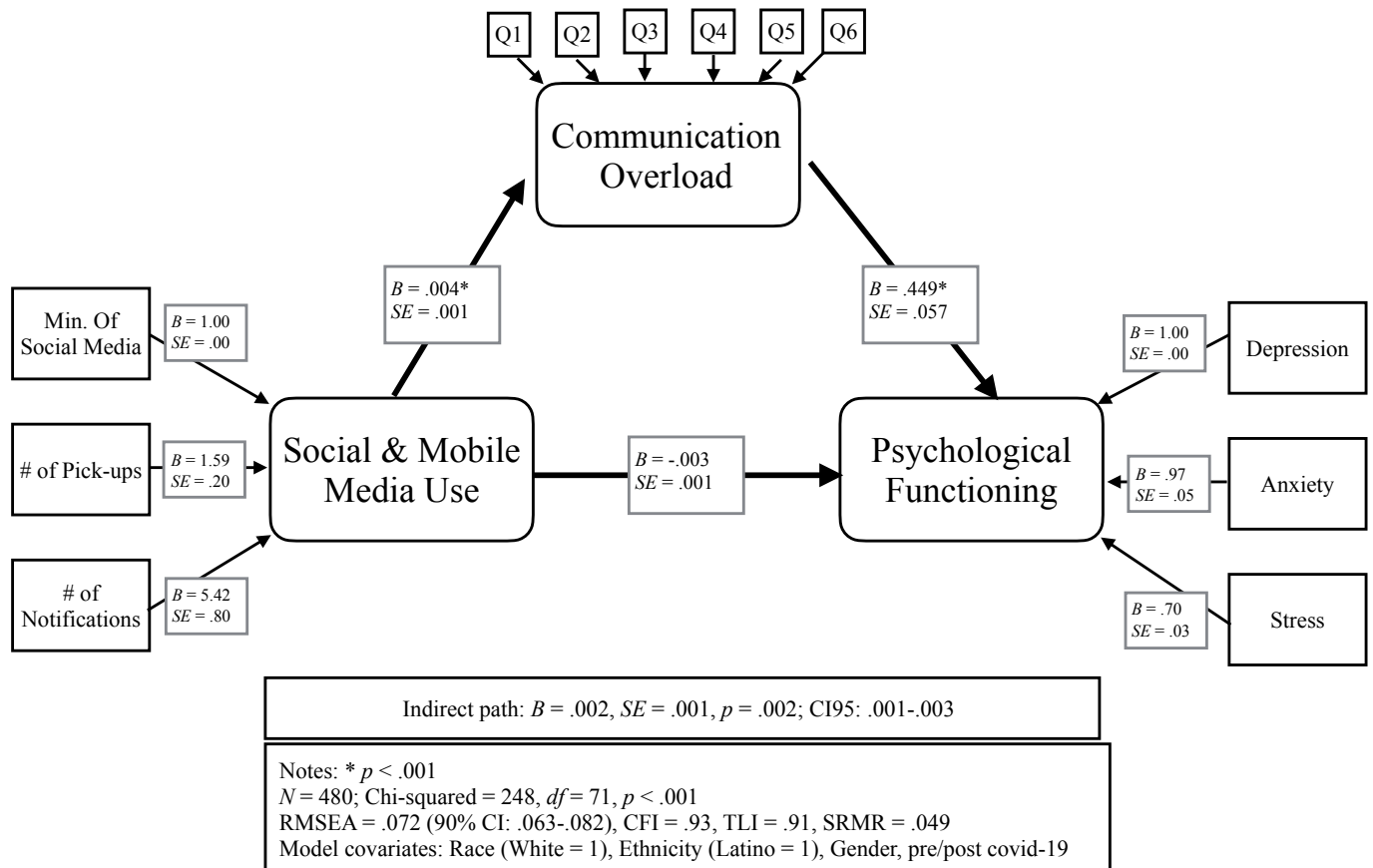
Variables	1	2	3	4	5	6	7	8	9	10	11
1. SM Time		.18*	.56***	.14	.09	.07	.13	.16*	.16*	.17*	.11
2. Pick-ups	.43***		.58***	.04	-.00	.01	-.02	-.07	.02	-.00	.04
3. Notifications	.37***	.65***		.09	.04	.14	.17*	.11	.12	.18*	.14
4. Overload	-.03	.20**	.18**		.47***	.48***	.41***	.38***	.35***	.32***	.34**
5. Availability Stress	.08	.17**	.10	.45***		.51***	.46***	.48***	.22**	.25***	.19**
6. Approval Stress	.01	.05	-.08	.44***	.44***		.70***	.33***	.53***	.52***	.46**
7. FoMO	-.06	.02	-.07	.40***	.40***	.57***		.38***	.57***	.60***	.53**
8. Vigilance	.06	.12	.07	.42***	.49***	.55***	.48***		.18**	.24***	.17*
9. Stress	.06	.04	-.05	.36***	.20**	.37***	.47***	.24***		.78***	.74**
10. Depression	-.01	-.03	-.07	.27***	.13*	.28***	.40***	.20**	.68***		.80**
11. Anxiety	.03	.05	-.06	.38***	.21**	.39***	.43***	.28***	.67***	.72***	
12. Social relationships	.05	.19**	.23***	.10	.08	-.10	-.17**	-.04	-.21**	-.20**	-.10

Notes. \* $p < .05$ . \*\*  $p < .01$ . \*\*\* $p < .001$



Figure One

Connection Overload as Mediator for Complete Sample



### **Supplemental Materials**

#### On the use of different psychological functioning measures

Prior to data collection we had to choose between two options in measuring psychological functioning: use the same scale for both young adults and adolescents or use age-appropriate measures that used different items. For perceived stress, we elected to use the same measure (Cohen et al., 1983) to be in dialogue with past research and because digital stress has a conceptual focus on stress. For the remaining three measures (i.e., depression, anxiety, companionship) we elected to use age-appropriate measures developed by the National Institutes of Health (<http://nihpromis.org>). One of the consequences of this decision was tests of invariance cannot be conducted to show that the items load similarly between samples for each of the three sub-components of psychological functioning. We felt that this decision was superior to using measures designed for young adults on adolescents or vice versa. Essentially, we traded off the benefits of measuring psychological functioning using established, validated, and age-appropriate measures of the same concept (e.g., depress) with the potential statistical challenges of using different items to measure the same concept. There are no existing, age-appropriate measures that have the identical items

We feel there is good reason to believe that the benefits were superior to the losses. Meta-analysis assumes that research findings are transferable when different measures of the same concept are used. Indeed, various measures of well-being are combined in analyses of the effects of social media (e.g., Huang, 2017). In our study, we measure the same three concepts with different yet age-appropriate items. In meta-analysis, the mean effect size is extracted and compared between samples, and when the mean effect sizes are similar between different measures (i.e., homogenous), then the presumption can be made that the measurement of the

concept itself did not influence the association between concepts. Experimental researchers make a similar assumption when they use different manipulations of the independent variable to confirm a similar tendency in the data. Our position is, when the measures are valid and appropriate for the participants, then associations derived from those data can be analyzed and interpreted in a similar fashion. We explore the statistical consequences of this choice below.

#### *Moderation of Digital Stress with Psychological Functioning by Sample*

Three measures of psychological functioning were measured differently by sample. Thus, two relationships, between digital stress and functioning and between mobile and social media use and functioning, could have been affected by the difference in measurement. The results of the moderation mediation models suggested that the first association (digital stress and functioning) were not moderated by sample. Table A below reports the results of 20 tests of moderation by sample. These results demonstrate that only 2 (i.e., approval anxiety and FOMO and depression) of the 20 possible relationships between digital stress and psychological functioning varied by sample. This confirms the results of the moderated mediation, which combined stress, depression, and anxiety into psychological functioning. These results suggest that for identical measures shared by adolescents and young adults (i.e., stress) and for measures that used different items, the pattern of relationships were identical between samples.

#### *Moderation of Mobile and Social Media Use and Psychological Functioning by Sample*

As reported in the text, there was a moderation by sample for this relationship; across all five models, the direct effect ( $c'$ ) was moderated by age. It is plausible that this distinct pattern of results is due to different items measuring 3 of the psychological functioning between samples. However, given the pattern of results reported for digital stress and the arguments above, we believe that this moderation is still interpretable, given the caveat of different measurement.

Table A: Moderations of sample for digital stress on psychological functioning relationship

	Depression				Anxiety				Social Roles				Perceived Stress			
	<i>B</i>	<i>SE</i>	<i>p</i>	<i>R2 chg</i>	<i>B</i>	<i>SE</i>	<i>p</i>	<i>R2chg</i>	<i>B</i>	<i>SE</i>	<i>p</i>	<i>R2-chg</i>	<i>B</i>	<i>SE</i>	<i>p</i>	<i>R2-chg</i>
Availability	-0.140	0.100	0.130	0.004	0.060	0.090	0.540	0.001	0.050	0.070	0.500	0.001	-0.020	0.070	0.800	0.000
Approval	-0.260	0.070	<b>0.000</b>	0.020	-0.020	0.070	0.840	0.000	0.120	0.060	0.040	0.010	-0.120	0.050	0.020	0.010
FoMO	-0.250	0.070	<b>0.001</b>	0.020	-0.040	0.080	0.630	0.000	0.100	0.060	0.100	0.005	-0.080	0.050	0.120	0.004
Overload	-0.070	0.100	0.450	0.001	0.130	0.100	0.180	0.003	0.080	0.080	0.280	0.002	0.020	0.070	0.780	0.000
Vigilance	-0.100	0.090	0.300	0.002	0.130	0.090	0.140	0.004	0.050	0.070	0.520	0.001	0.020	0.060	0.710	0.000