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Concurrent and Subsequent Associations Between Daily Digital Technology Use and High-Risk Adolescents' Mental Health Symptoms

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Adolescents are spending an unprecedented amount of time using digital technologies (especially mobile technologies), and there are concerns that adolescents' constant connectivity is associated with poor mental health, particularly among at-risk adolescents. Participants included 151 adolescents at risk for mental health problems (M_{age} = 13.1) who completed a baseline assessment, 30-day ecological momentary assessment, and 18 month follow-up assessment. Results from multilevel regression models showed that daily reports of both time spent using digital technologies and the number of text messages sent were associated with *increased* same-day attention deficit hyperactivity disorder (ADHD) and conduct disorder (CD) symptoms. Adolescents' reported digital technology usage and text messaging across the ecological momentary assessment (EMA) period was also associated with poorer self-regulation and increases in conduct problem symptoms between the baseline and follow-up assessments.

The majority of adolescents in the United States now own a mobile phone and are frequently using mobile technologies as their primarily means of access to the Internet and engagement with social media (Lenhart, 2015). Adolescents spend, on average, 9 hours (h) a day using screen-based media including about 3 h/day on their mobile phones (Rideout, Pai, Saphir, Pritchett, & Rudd, 2015), and with a typical teen (the median) sending and receiving 30 texts per day (Lenhart, 2015). This high degree of connectivity has raised concerns about potential negative effects of mobile technology usage in particular, and digital technology use more broadly, on adolescents' mental health (George & Odgers, 2015).

There are a number of theories about how the amount of time spent using digital technologies (i.e., social networking tools, text messaging, and the Internet) may influence adolescents' mental health symptoms, especially for adolescents already experiencing mental health problems. It has been argued that spending time online "displaces" time spent on social or cognitively stimulating activities (i.e., displacement hypothesis), which in turn may increase feelings of social isolation or depression (Kraut et al., 1998; Nikklen, Valkenburg, & Huizinga, 2014). Others suggest that adolescents with preexisting problems may spend more time online to compensate for a lack of social skills (i.e., social compensation); that is, technology related problems may stem from, or simply reflect, adolescents' preexisting mental health problems (Shapira et al., 2003; Valkenburg & Peter, 2007; Widyanto & Griffiths, 2006). For adolescents with existing mental health problems such as attention deficit

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hyperactivity disorder (ADHD) or depression, there are also concerns that digital technology use may amplify offline symptoms by, for example, further isolating at-risk adolescents through solitary (compared to communicative) online activities (Kraut et al., 2002; Selfhout, Branie, Delsing, ter Bogt, & Meeus, 2009) and/or leading to problems with sustained attention and focus due to multitasking (Scott, Valley, & Simecka, 2016). In short, it is possible that an association between time spent online and mental health problems represents causal, selection-driven, or bidirectional effects and that adolescents with existing mental health problems may be at especially heightened risk for any negative effects. In the present study, we intensively follow a sample of young adolescents at risk for mental health problems via a mobile phone-based ecological momentary assessment (EMA) study and test whether reported digital technology use is associated with elevations in same day mental health symptoms and subsequent self-regulation and conduct problem behaviors.

Historically, the amount of time spent online has been associated with increased mental health problems among adolescents, including internalizing (Bickham, Hswen, & Rich, 2015; Kraut et al., 1998; van den Eijnden, Meerkerk, Vermulst, Spijkerman, & Engels, 2008; Ybarra, Alexander, & Mitchell, 2005) and externalizing (Leena, Tomi, & Arja, 2005; Swing, Gentile, Anderson, & Walsh, 2010; Zheng et al., 2014) problems. For example, a nationally representative, cross-sectional study of approximately 1,500 adolescents in the late 1990s found that adolescents who used the Internet more frequently also reported greater symptoms of depression (Ybarra et al., 2005); 27% of adolescents reporting major depressive symptoms also reported spending 3 or more hours per day on the Internet as compared to only 15% of adolescents with minor and 13% with no symptoms. A recent meta-analysis of 45 studies found that time spent using electronic media (i.e., watching television, playing video games) had significant, but often small, positive associations with ADHD symptoms, including impulsivity and attention symptoms (Nikklen et al., 2014).

Longitudinal studies have also shown that children who spend more time online are at increased risk for later mental health problems. For example, the HomeNet study of 93 families found that adolescents' average weekly number of hours spent online (as measured by computer logs for 50–100 weeks) after the Internet was first introduced into their homes predicted increases in depressive symptoms 1–2 years later (Kraut et al., 1998). A more recent 14-day diary study of 82 college students found that daily Facebook use was associated with more negative daily mood and that greater average weekly usage predicted increased depressive symptoms and lower life satisfaction at the end of the week (Kross et al., 2013). Similarly, a longitudinal study of nearly 1,300 children (ages 8–11) showed that time spent watching television and playing video games predicted increases in attention problems 13 months later (Swing et al., 2010).

It is difficult to draw conclusions from past research about the potential effects of digital technology usage on mental health problems among contemporary adolescents for the following reasons. First, many of the studies reporting associations between time spent online and mental health problems were conducted in the late 1990s and early 2000s when only a small minority of adolescents were online frequently and when online communication was characterized by conversing with strangers in online chatrooms. Today, nearly all adolescents are online and primarily communicate with friends and family from adolescents' "offline" lives (Underwood, Ehrenreich, More, Solis, & Brinkley, 2015). For reference, in 1995, only 14% of the U.S. adult population had access to the Internet and by the year 2000, only 53% owned a mobile phone and 46% had access to the Internet, compared to 92% and 87%, respectively, in 2015 (see national data from the Pew Research Center, Fox & Rainie, 2014). Historical differences are important to consider when interpreting findings and definitions as technology usage has changed immensely over the last 20 years, with greater ease of online access, modes of contact, and variety of partners and spaces to explore. Second, research linking mental health and digital technology use has often focused on the amount of time spent viewing passive media (i.e., TV) or violent media (i.e., video games) versus time spent with digital devices and in more active forms of online communications and activities. Third, the majority of research has relied on cross-sectional and retrospective reports of technology usage patterns and mental health symptoms (with some notable exceptions, e.g., Ehrenreich, Underwood, & Ackerman, 2014; Underwood et al., 2015). Daily methods, like the EMA (Shiffman, Stone, & Hufford, 2008) study presented here, are useful for capturing adolescents' reported digital technology usage and mental health symptoms "in the moment" and for examining the within-individual coupling of these phenomena over time. Research

with contemporary adolescents is needed to understand the daily interplay between digital technology usage and mental health symptoms and to test whether digital technology use during early adolescence predicts later problems. This is especially true for at-risk adolescents, given evidence of what has been referred to as a "new digital divide" whereby more affluent adolescents are reported to spend more time engaged in online activities with parents and other adults, which may confer benefits associated with adult mediated technology usage, whereas lower income children spend more time interacting with technology alone or with peers in unstructured activities, which may carry more risks (Micheli, 2016).

The present study examines the associations between reported daily digital technology usage and symptoms of anxiety, depression, ADHD, and conduct disorder (CD) among young adolescents. In this study, we address two about high-risk adolescents from from low socioeconomic neighborhoods: (a) Is the amount of reported daily digital technology usage associated with adolescents' same-day and next-day mental health symptoms? and (b) Does the amount of reported digital technology usage during early adolescence predict their later self-regulation deficits and conduct problems?

Method

Participants

The miLife Study used EMA via mobile phones to track the daily experiences, behaviors, and emotions of 151 young adolescents at heightened risk for mental health problems (for full study details, see Russell, Wang, & Odgers, 2015). Approximately 80% of the adolescents reported the presence of at least one CD symptom (e.g., fighting, destroying property, use of weapons, stealing), whereas 50% endorsed three or more symptoms of CD (the minimum number required for a CD diagnosis), placing this sample well above population-based estimates of CD prevalence in the United States, which is approximately 9.5% (male = 12.0%, female = 7.1%; Nock, Kazdin, Hiripi, & Kessler, 2006) and ranges from 4.4% to 9.6% for severe behavioral disorders in more recent studies (Merikangas et al., 2010). Participants ranged in age from 11 to 15 years (M = 13.1, SD = 0.91). The sample was 48% female and ethnically diverse (57.3% White, 23.3% Hispanic, 4.0% African American, 4.7% Native American, 4.0% Asian, with the remaining identifying as belonging to another category). The participants were from low socioeconomic status neighborhoods. One in three families in the sample "occasionally" or "often" had difficulty paying for food or other necessities, 40% reported difficulties paying for bills, and 8% reported that they were currently receiving government services or assistance. The University of California Irvine Institutional Review Board approved all measures and procedures in the study.

Procedure

Adolescents were recruited if the parent reported the presence of three or more risk factors during a brief telephone screen (i.e., behavioral difficulties, inattention or hyperactivity, substance use, or exposure to substances). Parents and their children provided their consent/assent to participate. This study had three phases: a baseline assessment, an EMA, and an 18-month follow-up assessment (Figure S1). The follow-up assessment completed in spring 2012 when 93% of the original study members (n = 141) completed in-person assessments. At baseline, parents and adolescents both completed a set of self-report inventories about family characteristics, experiences, and the adolescents' mental health problems. During the EMA, adolescents were provided smart phones programmed with the adolescents' normal schedules to "beep" three times a day for 30 consecutive days. The morning survey (i.e., 7–10 a.m.) took approximately 2.3 min, the afternoon survey (2–5 p.m.) took approximately 3.8 min, and the evening survey (5 p.m.–12 a.m.) took approximately 8.3 min to complete. The average response rate across the mobile assessment period was 92%, resulting in over 13,000 assessments and 4,329 person days for analysis. At the follow-up assessment, adolescents' self-regulation and conduct problem symptoms were reassessed. (See Figure S1 for a diagram of the study design.)

Measures

Daily Digital Technology Usage

Digital technology usage was reported by adolescents each night during the EMA and was measured in the following three ways. First, adolescents estimated the *amount of time* they spent using digital technologies each day, including the number of hours each day spent: (a) using social media, (b) using the Internet, and (c) texting. Second, these three daily measures were combined into a global measure of "time spent online (hours)" using digital

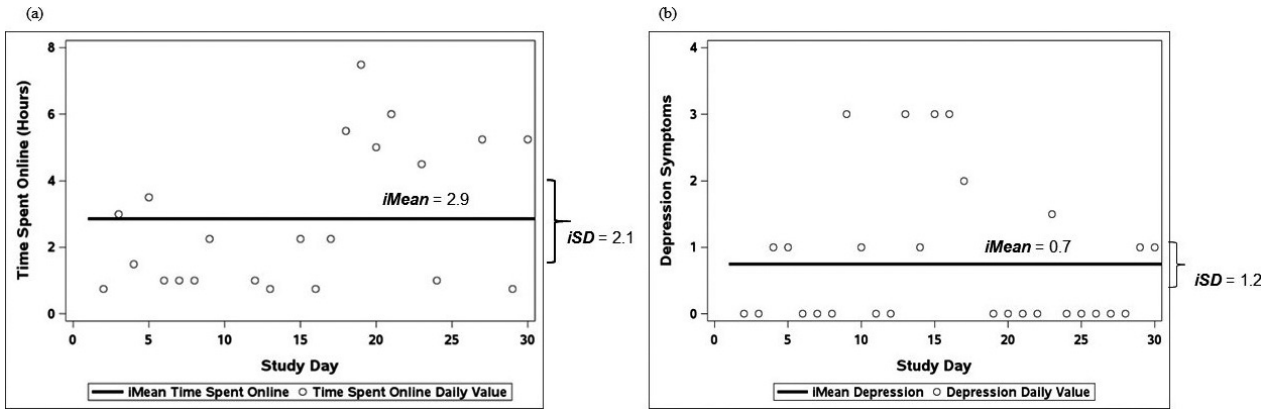

Figure 1. Intraindividual mean (iMean) and intraindividual standard deviation (iSD) for time spent online (a) and depressive symptoms (b) across study days for a single adolescent. The iMean [$\bar{x}_j$] is calculated using the formula $\bar{x}_j = \frac{\sum_{i=1}^{n_j}(x_i)}{n_j}$, where $\sum_{i=1}^{n_j}(x_i)$ is the sum of all daily observations [x_i] for adolescent j, and n_j is the total number of daily reports provided by adolescent j. iSD [σ_j] is calculated using the formula $\sigma_j = \sqrt{\frac{\sum_{i=1}^{n_j}(x_i - \bar{x}_j)^2}{n_j - 1}}$; the iSD is the square root of the sum of squared deviations of all daily observations from the iMean $\left[\sum_{i=1}^{n_j}(x_i - \bar{x}_j)^2\right]$, divided by the total number of daily observations for adolescent j minus 1[$n_j - 1$].

Table 1
*Means, Standard Deviations, and Ranges for Aggregated Person-Level Measures of Daily Digital Technology Use and Mental Health Symptoms (*N = *151)*

	Total *M* (*SD*)	Range
Digital technology use (mean daily use)		
Time spent online (hours)	2.29 (1.34)	0.75–8.14
Time spent on social media (hours)	0.24 (0.39)	0–2.59
Time spent on the Internet (hours)	0.93 (0.58)	0.5–3.23
Time spent on texting (hours)	1.15 (0.89)	0.5–4
Texts sent	40.61 (70.10)	0–374.39
Mental health symptoms (% of days with 1+ symptoms)		
Anxiety (%)	0.32 (0.29)	0–1
Depression (%)	0.27 (0.27)	0–1
ADHD (%)	0.28 (0.26)	0–1
CD (%)	0.09 (0.15)	0–0.93

Note. ADHD = attention deficit hyperactivity disorder; CD = conduct disorder.

technologies. Figure 1a illustrates the daily reports of *hours spent using digital technologies* each day for a single adolescent and illustrates how the iMean (the mean of reported daily usage for this individual across the 30 days) and the iSD (the intraindividual standard deviation for this individual across the 30 days) were computed for each adolescent. In Table 1, we report the EMA summary statistics (the iMean and iSD) to summarize adolescents' average daily digital technology usage across the 30 day EMA. As shown in Table 1, adolescents reported spending, on average, approximately 2.3 h using digital technologies per day, with, on average, 1.15 h spent text messaging. Third, adolescents reported the *number of text messages they had sent* each day. Adolescents reported sending, on average, 41 text messages per day across the 30-day EMA.

The intraclass correlations (ICCs) were calculated in a multilevel modeling (MLM) framework for time spent online (.44) and the number of texts sent (.45) which shows, for example, that 44% of the variance in reported daily *time spent online* was between adolescents, whereas the remaining 56% [(1 − ICC) × 100] of the variance was within adolescents over time.

Two of the measures (number of hours spent texting and number of text messages sent) capture usage from mobile phones only. However, for the reported hours spent on social media and on the Internet it was not possible to separate the amount of time that adolescents' engaged in these activities using mobile versus other devices. It was likely, but not tested, that much of the reported daily social media and Internet usage occurred via mobile devices, as most adolescents, and especially those from low-income families, have access to smart phones and report daily access to the Internet via their phones (Lenhart, 2015). Thus, only two "pure" measures of mobile

device usage (reported time spent texting and number of text messages sent each day) are reported here, alongside two hybrid measures of digital technology usage (time spent using social media and the Internet), which may include usage across multiple platforms (e.g., mobile devices and desktop computers).

Adolescents' reported digital technology use was assessed via daily EMAs administered through mobile phones. EMA offer three key benefits in relation to traditional self-reported assessments. First, most surveys and interviews ask participants to recall their past experiences, symptoms, and behaviors across a given length of time (e.g., over the last "6 months" or "week"). However, recall bias in self-reported experiences is well documented (Bradburn, Rips, & Shevell, 1987; Stone, Bachrach, Jobe, Kurtzman, & Cain, 1999), especially when reporting on mundane and frequent experiences (Schwarz, 2007), such as adolescents' digital technology usage. Second, EMA allowed for the capture of reported technology usage in adolescents' naturalistic environment as they went about their daily lives. Context has well-documented effects on adolescents' behaviors (Duncan & Raudenbush, 1999), and EMA strategies have been shown to both reduce recall bias and enhance ecologically validity of self-reports (Bolger, Davis, & Rafaeli, 2003; Shiffman, 2009; Shiffman et al., 2008). Third, the high-resolution data gathered via by EMA allow for an analysis of dynamic processes over time (Stone et al., 2007), including tests of daily within-individual coupling of symptoms and technology usage, while also capturing novel assessments of daily digital technology usage that could be used to predict later mental health symptoms.

Daily Depression, Anxiety, ADHD, and CD Symptoms

Mental health symptoms were measured each day using items adapted for use in the EMA context from (a) diagnostic criteria in the *Diagnostic and Statistical Manual of Mental Disorders* (4th ed. [*DSM–IV*]; American Psychiatric Association, 1994), (b) widely used symptom scales for child and adolescent psychopathology (e.g., Beck Depression Inventory, Rutter Child Scales), and (c) prior EMA protocols developed for assessing children and adolescents' symptoms in daily life (Whalen et al., 2006).

Depression and anxiety symptoms were measured three times throughout the day: in the morning, after school, and in the evening. Depressive symptoms were measured using items modified for EMA from the Beck Depression Inventory (Beck, Sterr, & Brown, 1996). Adolescents responded to five items measuring symptoms such as sadness (e.g., "I feel sad"), hopelessness (e.g., "I feel hopeless, like nothing matters"), and guilt (e.g., "I feel guilty for no reason"; yes/no). Adolescents reported on the presence (yes/no) of four anxiety symptoms (e.g., "I am worried," "I feel afraid") adapted from the Multidimensional Anxiety Scale for Children (March, 1997). Daily depression (ICC = 0.42) and anxiety (ICC = 0.37) symptom measures were created by summing the total number of symptoms across the day. Figure 1b displays the reported depression symptoms each day by a single adolescent in our study and illustrates how the iMean and iSD for the adolescent were computed across the EMA series.

Attention-Deficit Hyperactivity Disorder symptoms were measured once daily in the after school diary as the presence (yes/no) of four ADHD symptoms (e.g., "I had a hard time concentrating/focusing," "I felt restless or like I was always on the go") using items adapted from the *DSM–IV* symptom checklist and used in prior EMA studies with ADHD children (Whalen et al., 2006). Daily symptom measures were created by summing the total number of symptoms across the day. Daily ADHD symptom measures were created by summing the total number of symptoms across the day (ICC = 0.35).

Conduct problem symptoms were measured in the evening diary each day using six items (yes/no) measuring aggression (e.g., "Today did you hit or hurt someone?"), vandalism (e.g., "Today did you damage someone else's property?"), and theft (e.g., "Today did you steal something that did not belong to you?"), and bullying (e.g., Did you bully, ignore, say mean things, or tell lies about someone?) adapted for the EMA based on CD symptoms listed in the *DSM–IV* (American Psychiatric Association, 1994) and from the Child Behavior Checklist (CBCL; Achenbach & Rescorla, 2001). Daily conduct problem symptom measures were created by summing the total number of symptoms across the day (ICC = 0.22).

Baseline and Follow-Up Measures of Mental Health

Conduct problem symptoms were assessed at both baseline and the 18-month follow-up using a conduct problem symptom scale developed for use in large-scale epidemiological studies (Kim-Cohen et al., 2005) based on *DSM–IV* CD symptoms and modified items from the CBCL (Achenbach &

Rescorla, 2001). Parents and adolescents completed the measure at the baseline and the adolescent was assessed at the follow-up. The symptom scale includes 11 symptoms of CD (e.g., Does your child get into many fights? Does your child destroy things that belong to other people?). Each item was rated on a three-point scale of 0 (*not true*), 1 (*somewhat/sometimes true*), and 2 (*very/often true*) in the past 6 months. A summary score of the 11 conduct problem behaviors assessed at both waves was created at the baseline ($M = 2.46$, $SD = 2.07$) and follow-up assessments ($M = 2.47$, $SD = 2.19$).

Symptoms of attention deficit and hyperactivity disorder were assessed at the baseline assessment from parents' reports of seven items concerning inattention, hyperactivity, and impulsivity (e.g., Does your child often forget what he/she is doing?) using items derived from the *DSM–IV* diagnostic criteria for ADHD (American Psychiatric Association, 1994) and the Rutter Child Scales indexing ADHD symptoms (Sclare, 1997; $M = 4.23$, $SD = 3.19$). *Poor self-regulation* was measured via adolescent self-report at the follow-up assessment using the 13-item Brief Self-Control Scale (Tangney, Baumeister, & Boone, 2004), which rated each item on a three-point scale ranging from 0 to 2 ($M = 10.62$, $SD = 4.77$).

Analytic Strategy and Statistical Models

Analyses proceeded in three steps. First, to test whether reported daily digital technology usage was associated with mental health symptoms, multilevel models (Raudenbush & Bryk, 2002), specified in Stata version 13, were used to account for the nesting of days within adolescents and to estimate within-person associations between usage and symptoms. Symptom counts were modeled using a Poisson distribution. Incident rate ratio (IRR) effect sizes were calculated by exponentiating the fixed effects from the Poisson multilevel models and display the proportional change in symptom counts with each unit increase in digital technology use.

Second, cross-lagged multilevel models were specified using Mplus Version 6 to test whether technology use predicted next-day mental health symptoms and similarly whether mental health symptoms were associated with next-day symptom use. Lagged mental health and technology use measures were centered around each adolescent's mean to remove between-person variance in the within-person lagged effects (Bolger & Laurenceau, 2013).

Third, ordinary least squares (OLS) regression analyses were conducted to assess whether the participants' reported average daily digital technology usage during the 30-day EMA predicted poor self-regulation and conduct problems 18 months later, controlling for baseline reported ADHD symptoms (when predicting poor self-regulation) and for baseline CD symptoms (when predicting later conduct symptoms).

Results

Table 1 shows the means and standard deviations of daily digital technology usage and mental health symptoms among the sample. Adolescents reported spending, on average, 2.29 h online each day and sending, on average, 41 text messages. The proportion of study days where the adolescents reported more than one symptom of anxiety, depression, ADHD, and CD are also displayed. Across over 4,300 study days, adolescents reported experiencing at least one anxiety symptom on 32% of days and at least one depression symptom on 27% of study days; ADHD and CD symptoms were recorded on 28% and 9% of study days, respectively.

Table 2
Multilevel Poisson Model Coefficients and 95% Confidence Intervals Showing the Daily Associations Between Digital Technology Use and Same-Day Mental Health Symptoms

	Same day mental health symptoms			
	Anxiety *b* [95% CI]	Depression *b* [95% CI]	ADHD *b* [95% CI]	CD *b* [95% CI]
Time spent online	−0.03 [−.05, −.003]*	−0.005 [−.03, .02]	0.05 [.02, .08]**	0.13 [.07, .19]***
Time spent on social media	−0.05 [−.11, .01]	−0.05 [−.11, .01]	0.11 [.03, .18] **	0.21 [.07, .34]**
Time spent on the Internet	−0.02 [−.07, .03]	0.01 [−.04, .06]	0.008 [−.05, .07]	0.19 [.06, .31]**
Time spent on mobile phone (texting)	−0.05 [−.09, −.01]*	−0.005 [−.05, .04]	0.10 [.04, .17]**	0.22 [.10, .33]***
Texts sent (tens)	−0.006 [−.01, −.002]**	−0.008 [−.01, −.002]**	−0.001 [−.009, .007]	0.02 [.003, .03]*

Note. ADHD = attention deficit hyperactivity disorder; CD = conduct disorder. *$p < .05$. **$p < .01$. ***$p < .001$.

Daily Digital Technology Usage Is Associated With Same-Day Mental Health Symptoms

Table 2 shows the results for multilevel models examining the same-day within-person associations between reported digital technology use and continuous symptoms of anxiety, depression, ADHD, and CD. Findings from this table illustrate two main points. First, the amount of time that adolescents reported spending online on a given day was positively associated with their reported same-day symptoms of ADHD and CD ($b = 0.05$, $p = .002$, IRR = 1.05 and $b = 0.13$, $p < .001$, IRR = 1.14, respectively). For CD symptoms, there was a positive and significant coupling of same-day symptoms across all five measures of reported daily digital technology usage, including for number of texts sent ($b = 0.02$, $p = .01$, IRR = 1.02). For ADHD, reported time spent on social media and time spent texting on the mobile phone were significantly associated with daily symptoms, whereas reported time spent on the Internet was not. There was no evidence of a same-day association between daily reports of the number of text messages sent and ADHD symptoms.

Second, although the effect sizes were small, adolescents reported slightly fewer anxiety ($b = -0.03$, $p = .03$, IRR = 0.97) symptoms on days when they spent more time online, with a statistically significant association between more reported time spent texting and fewer anxiety symptoms on a given day. Adolescents also reported fewer anxiety ($b = -0.006$, $p = .007$, IRR = 0.99) and depression symptoms ($b = -0.008$, $p = .006$, IRR = 0.99) on days where they sent more text messages, which represent statistically significant but small associations.

Reported ADHD Symptoms Are Associated With Next-Day Digital Technology Usage

Cross-lagged MLMs were used to estimate the same (concurrent) and next-day (lagged) associations between daily reports of time spent online and mental health symptoms. This model was used to test for associations between reported daily digital technology use and the four types of mental health symptoms assessed during the EMA (full details of each of the eight models are reported in Table S1). Two main sets of findings emerged from these analyses. First, there were significant autoregressive associations for reported time spent online lagged on itself by 1 day ($\beta = .35$, $p < .001$), for reported number of text messages sent lagged on itself by 1 day ($\beta = .31$, $p < .001$), and for all mental health symptoms lagged by 1 day (autoregressive correlations ranged from $\beta = .14$ to 0.27). Second, across eight models, evidence for a next-day (cross-lagged) association between daily technology use and mental health symptoms was found for *only one* pathway. That is, increases in reported daily ADHD symptoms were associated with increases in *next*-day time spent online (see Figure S2, path d; $\beta = .05$, $p = .006$). However, more reported time spent online was not associated with increases in next-day ADHD symptoms ($\beta = .03$, $p = .19$; see path e). No other cross-lagged associations were statistically significant.

Daily Digital Technology Usage Predicts Later Self-Regulation and Conduct Problems

Finally, we tested if there were predictive associations between reported daily digital technology use during early adolescence and later self-regulation or conduct problems. Adolescents who reported more time spent using digital technologies and sending more text messages across the EMA exhibited higher levels of conduct problems at the follow-up assessment (Figure S3a and b). These associations held after controlling for baseline conduct problem symptoms. That is, the average amount of reported time spent online and the average number of text messages sent during the EMA predicted *increases* in conduct problems symptoms from the baseline to the follow-up assessment, $b = 0.31$, 95% CI = [.06, 0.57], $p = .02$, $\beta = .19$ and $b = 0.06$, 95% CI = [.02, 0.11], $p = .007$, $\beta = .20$.

In addition, the average amount of reported time spent online during the EMA period predicted later self-regulation problems, also after controlling for baseline ADHD symptoms, $b = 1.18$, 95% CI = [.58, 1.77], $p < .001$, $\beta = .32$. For each additional hour spent online during the EMA, the adolescent's self-regulation score was predicted to increase by over 1 point on the self-regulation score. In standardized terms, for each additional 1.5 reported hours online an adolescent's self-regulation score was predicted to increase by 0.32 of a standard deviation. The average number of texts sent across the EMA did not predict later self-regulation problems after controlling for baseline ADHD symptoms, $b = 0.08$, 95% CI = [−.04, 0.20], $p = .21$, $\beta = .11$.

Discussion

This study used EMA to examine the momentary and longitudinal associations between daily digital

technology usage and mental health symptoms during early adolescence and advances what is known about this topic in three ways. First, although the effects were small (IRRs ranged from 1.02 to 1.4), there was a robust association between adolescents' reported daily digital technology usage and same-day symptoms of ADHD and CD. Recent research suggests that the content of adolescents' text messages may also be a marker of adolescents' involvement in antisocial behavior (Ehrenreich et al., 2014). Future research is required to test whether digital and mobile technology usage may mark, or create, opportunities for offline deviant behaviors.

Interestingly, on days that adolescents reported spending more time online and sending more text messages, they also reported fewer symptoms of anxiety. Similarly, on days that adolescents reported sending more text messages, they reported fewer symptoms of both depression and anxiety. The same-day associations between internalizing problems and digital technology use were very small (IRRs around 0.99). Nonetheless, these effects are inconsistent with older research that documented positive associations between depression and greater amounts of time spent on the Internet or social media (Kraut et al., 1998; Kross et al., 2013; Willoughby, 2008; Ybarra et al., 2005). These findings are consistent with an emerging body of research suggesting that the association between depression and time online may *not* hold in samples of contemporary adolescents who may be using their time online to connect in more positive ways with their social network (Valkenburg & Peter, 2009). It is also possible that these adolescents, who were already suffering from mental health problems, used digital technologies to cope with or distract themselves from ruminative and negative thoughts and symptoms. Alternatively, adolescents may simply be more active online (and offline) on asymptomatic days. Future research is required to test whether these findings generalize beyond this high-risk sample.

Second, on days when adolescents reported experiencing ADHD symptoms they also reported spending more time online the following day. There were no next-day associations from technology usage to symptoms. Our finding suggests that when adolescents are experiencing attentional problems they may be more likely to use (or overuse) digital technologies the next day, which is consistent with the idea that adolescents with preexisting mental health problems may be selecting into more frequent usage patterns. A recent 7-day study of college students found that sleep debt was associated with greater next-day attentional problems and social media use (Mark, Wang, Niiya, & Reich, 2016); additional research connecting offline symptoms and behaviors with daily technology usage is needed.

Third, higher levels of digital technology usage during early adolescence predicted poor self-regulation and increases in conduct problems between the baseline and 18 month follow-up assessment. These effects fell within small to moderate range (βs ranged from .11 to .32) and are consistent with other studies showing that time spent using electronic devices is associated with greater attentional problems and externalizing symptoms (Nikklen et al., 2014). Unfortunately, we were unable to examine whether digital technology usage predicted later internalizing symptoms, as depression and anxiety were not assessed at the follow-up assessment. The findings are novel in that they suggest that the amount of daily digital technology use during early adolescence predicts *increases* in conduct problems over time and later self-regulation problems. For conduct problem symptoms this was true for our aggregate measure of time spent online and for our specific measure of "text messages sent," which reflect a mobile-only form of digital technology engagement. Given the importance of early self-regulation abilities for later mental health and well-being (Moffitt et al., 2011; Tangney et al., 2004), it will be important to test the interplay among digital technology usage, attention, and self-regulation in larger, more representative samples and within experimental paradigms that facilitate causal inference.

This study also had limitations. First, self-reports of technology usage and mental health symptoms were used in this study raising the possibility that shared method variance bias could be driving the associations. Ideally, high-resolution measures of digital technology usage across devices would have been available from both self-reported and more objective phone record and/or device log data to help assess and account for same-day recall bias. The inclusion of objective measures of digital technology usage in future studies will be especially important given that traditional self-report assessments tend not to be well correlated with objective measures of usage, such as phone logs (Boase & Ling, 2013; Gold, Rauscher, & Zhu, 2015). Future EMA research with adolescents is also required to evaluate whether daily reports provide an improvement over traditional self-report data for these purposes. Newer methods of tracking digital online use across adolescents' devices should be considered in future studies, especially for studies that

conduct mobile phone-based EMA on the adolescent's own phone. This is an important limitation and area for future research.

Second, we were not able to separate the reported time spent on social media or on the Internet from mobile versus other devices each day. We assumed based on large-scale surveys that most adolescents are accessing the Internet and social media from their mobile versus other devices (Lenhart, 2015), but we did not collect the information required to determine whether associations between digital technology usage and mental health symptoms differed depending on mobile versus other forms of access.

Third, study participants included adolescents already at risk for mental health problems, and it is not known whether the findings will generalize to the broader population of adolescents. Although our focus on at-risk adolescents allowed us to test questions that are of great interest to clinicians and parents of children suffering from mental health problems, replications in larger and more representative samples of young people are needed.

Fourth, although we examined the association between digital technology usage and mental health symptoms over time within an individual (controlling for important between-person fixed effects such as age, socioeconomic status, and gender), experimental work is needed to move beyond our observational design and test causal theories about the interplay between technology usage and adolescents' mental health.

Taken together, our findings reinforce the need for more research with contemporary populations of adolescents to rigorously test assumptions about the potential negative (and positive) effects of digital technology usage on adolescents' mental health. On the negative side, our findings suggest that contemporary adolescents' usage of digital technologies may mark, or exacerbate, problems related to poor self-regulation and conduct problems among already at-risk adolescents. On the positive side, we did not find evidence, among this population of adolescents with preexisting mental health problems, to support past research with older cohorts consistently linking more time spent online to greater depressive and internalizing symptoms. In fact, when a signal emerged from the daily assessments, it suggested that more time online and greater online communication was associated with fewer same-day internalizing symptoms. This may be explained in part by the nature of the online activities, as increased time spent online communicating with others (compared to solitary activities) has been associated with decreased depressive symptoms (Selfhout et al., 2009). More research is needed to understand whether at-risk adolescents may be using digital technologies to manage symptoms and whether such technologies can be effectively leveraged to improve mental health. Similarly, experimental studies are now needed to test whether reductions in digital technology usage during early adolescence can prevent or reduce future self-regulation and behavioral problems.

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Supporting Information

Additional supporting information may be found in the online version of this article at the publisher's website:

Table S1. Standardized Path Coefficients and 95% Confidence Intervals From the Cross-Lagged Multilevel Regression Models of Daily Digital Technology Use and Mental Health Symptoms

Figure S1. Study Design Timeline Illustrating the Three Phases of the Study: (a) A Baseline Assessment, Consisting of an In-Person Parent and Adolescent Interview (int.), (b) An Ecological Momentary Assessment (EMA) Study of the Adolescents via Mobile Devices for 30 Consecutive Days, and (c) An In-Person 18-Month Follow-Up Assessment With the Adolescent

Figure S2. Cross-Lagged Multilevel Model Showing the Standardized Coefficients for the Autoregressive, Same-Day, and Cross-Lagged Associations Between Daily Time Spent Online and ADHD Symptoms

Figure S3. (a) Predicted Regression Line Showing the Unadjusted Association Between Conduct Problems at the Follow-Up Assessment and the Average Hours Per Day Using Digital Technologies Across the 30-Day EMA With 95% Confidence Intervals, $b = 0.58$, $p < .001$, $\beta = .35$. (b) Predicted Regression Line Showing the Unadjusted Association Between Conduct Problems at the Follow-Up Assessment and Average Number of Daily Text Messages Across the 30-Day EMA With 95% Confidence Intervals, $b = 0.009$, $p < .001$, $\beta = .28$