



## Digital media use and suicidal behavior in U.S. adolescents, 2009–2017

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### ABSTRACT

U.S. adolescent suicidal behavior and digital media use prevalence have contemporaneously increased this decade in population-level ecological analyses. The purpose of this study was to determine whether these two trends are directly associated by using multi-year person-level data to test whether the association of year with suicidal behavior was mediated by digital media use. Data were from the Youth Risk Behavior Surveillance System (2009–2017), a nationally-representative biennial cross-sectional self-report survey of U.S. students (N = 72,942). Mediation analysis was used to estimate the proportion of cross-year changes in suicidal behavior that were mediated by concurrent changes in leisure-time digital media use. Past-year suicidal behavior in 2011 (19.6%), 2013 (20.4%), 2015 (21.7%), and 2017 (20.5%) increased relative to 2009 (17.1%). Hours of daily digital media use in 2011 (mean[SD] = 2.65[1.86]), 2013 (mean[SD] = 3.02[2.08]), 2015 (mean[SD] = 2.97[2.12]), and 2017 (mean[SD] = 3.01[2.18]) increased vs. 2009 (mean[SD] = 2.31[1.81]). The association of survey year with suicidal behavior was mediated by digital media use—20.5%(95%CI = 16.2, 24.8), 34.3%(95%CI = 24.5, 44.1), 22.8%(95%CI = 17.3, 28.0), and 41.4%(95%CI = 33.9, 49.5) of cross-year suicidal behavior prevalence increases (vs. 2009) for 2011, 2013, 2015, and 2017, respectively, were mediated by concurrent digital media use increases. Therefore, small proportions of the 2009–2017 increases in U.S. adolescent suicidal behavior are associated with concurrent increasing digital media use trends. Further exploration of these trends is warranted.

### 1. Introduction

Death by suicide and suicidal behaviors—suicidal thoughts, plans, or attempts—continues to increase among United States (U.S.) adolescents (Curtin and Heron, 2019; Ivey-Stephenson et al., 2020). Upward trends in adolescent suicidal behavior has been observed across youth self-report surveys (1.2-fold increase from 2009 to 2017) (Kann et al., 2018), hospitalization visit records (2.76-fold increase 2008–2015) (Burststein et al., 2019; Plemmons et al., 2018), and fatal injury registries (1.61-fold increase 2009–2017) (Miron et al., 2019). Paralleling the upward trends in adolescent suicidal behavior, the use of modern digital media platforms, including social media, texting, and videogames, has become

increasingly prevalent in the lives of youth (Twenge et al., 2018a, 2018b). Whether these two trends are directly associated with one another has garnered considerable interest (Odgers and Jensen, 2020).

The population-level ecological time trend analyses of adolescent digital media use and suicidal behavior that use time series analysis or other ecological methods has not been integrated with person-level observational research of the connection of these two behaviors (Orben and Przybylski, 2019; Shafi et al., 2019; Twenge and Campbell, 2019; Twenge et al., 2019a, 2018a, 2018b). Observational research of person-level data indicates that the association between digital media use and suicidal behavior is likely to be complex and is highly debated in the field; for some adolescents, digital media use may be associated with

**Abbreviations:** U.S., United States; YRBSS, Youth Risk Behavior Surveillance System; CDC, Centers for Disease Control and Prevention; OR, odds ratio; CI, confidence interval.

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greater wellbeing, while for others, digital media use may relate to poorer mental health (Odgers and Jensen, 2020; Orben and Przybylski, 2019; Shafi et al., 2019; Twenge and Campbell, 2019). For example, certain digital media platforms, such as social media, can be a source of social support from peers that one may otherwise not be able to be connected to Selkie et al. (2020). On the other hand, digital media use may also increase the likelihood of negative peer interactions; it may provide additional opportunities for cyberbullies to access their victims without geographical or time constraints, while also being able to maintain anonymity (Patchin and Hinduja, 2006). When taken together, these differential associations may sum to modestly worse mental health among high-frequency digital media users relative to the general adolescent population (Odgers and Jensen, 2020; Orben and Przybylski, 2019; Shafi et al., 2019; Twenge and Campbell, 2019).

It is also possible elevations in distress that accompanied suicidal behavior can increase the likelihood that one engages in digital media. The stress generation hypothesis postulates that individuals with depression are vulnerable to engaging in maladaptive coping strategies by virtue of having limited coping skills, whereby stress actually increases and emotional problems are worsened (Liu and Alloy, 2010).

Individuals with poor mental health may inadvertently exacerbate their symptoms by turning to digital media and engaging in maladaptive social behaviors (Scherr et al., 2018) such as social comparison and feedback seeking (Nesi et al., 2017). Therefore, engagement in digital media might be an appealing outlet for youth struggling with suicidality (Valentine et al., 2019), but may not actually alleviate symptoms.

Regardless of the mechanisms of their association, it is important to understand what portion of the increase in U.S. adolescent suicidal behavior is associated with increasing digital media use trends because it could provide guidance around digital technology in national policies and public health campaigns that counteract adolescent suicidal behavior. Because observational person-level and ecological population-level trend analyses have been conducted separately, direct estimates of the extent to which increases in suicidal behavior are associated with (and statistically attributable to) concurrent increases in digital media use are unknown. Such estimates can be calculated with mediation analysis of person-level data collected across multiple years (MacKinnon et al., 2007) that can provide information robust to ecological fallacy explanations that occur in time series analyses of population-level trends. Therefore, this study used mediation analysis to estimate the

**Table 1**  
Descriptive statistics of demographics and study variables.<sup>a</sup>

Variables	Pooled 2009–2017 <sup>b</sup>	By Year <sup>c</sup>				
		2009 <sup>c</sup>	2011 <sup>d</sup>	2013 <sup>e</sup>	2015 <sup>f</sup>	2017 <sup>g</sup>
<b>Demographics</b>						
Female sex	36,726 (49.3)	8099 (47.9)	7520 (48.8)	6497 (50.3)	7518 (48.8)	7092 (51.1)
Age, y						
13 or younger	248 (0.3)	41 (0.2)	62 (0.3)	40 (0.2)	51 (0.2)	54 (0.4)
14	7810 (10.9)	1591 (11.2)	1496 (11.5)	1332 (10.0)	1620 (10.1)	1771 (11.5)
15	16,949 (24.9)	3593 (24.6)	3347 (24.6)	3009 (24.1)	3662 (25.9)	3338 (24.9)
16	18,429 (25.6)	4040 (26.1)	3915 (26.1)	3101 (25.1)	3895 (25)	3478 (25.5)
17	18,432 (24.2)	4120 (24.3)	3826 (24.1)	3394 (24.8)	3710 (23.7)	3382 (24.2)
18 or older	10,753 (14.2)	2515 (13.6)	2220 (13.4)	2268 (15.7)	2074 (15.1)	1676 (13.4)
Race/ethnicity						
African American	12,299 (13.7)	2727 (14.3)	2600 (13.8)	2882 (14.1)	1567 (13.3)	2523 (12.9)
Hispanic	20,639 (20.7)	4651(18.6)	4494 (19.9)	3271 (20.9)	4913 (22.1)	3310 (22.4)
Other <sup>d</sup>	7639 (9.2)	1568 (8.2)	1497 (9.0)	1394 (8.8)	1575 (9.7)	1605 (10.2)
White	30,884 (56.4)	6732 (58.9)	6043 (57.3)	5374 (56.1)	6689 (54.9)	6046 (54.5)
Grade						
9th	18,553 (27.3)	4018 (27.7)	3618 (27.5)	3476 (27.2)	3828 (26.9)	3613 (27.2)
10th	17,714 (25.8)	3845 (26.4)	3556 (25.6)	3057 (25.6)	3794 (25.8)	3462 (25.5)
11th	18,306 (23.9)	3987 (23.6)	4014 (24.0)	3100 (23.9)	3790 (23.7)	3415 (24.0)
12th	17,803 (23.0)	4020 (22.3)	3620 (22.9)	3484 (23.3)	3522 (23.6)	3157 (23.3)
<b>Key Variables</b>						
Digital media use, mean (SD) <sup>e</sup>	2.78 (2.03)	2.31 (1.81)	2.65 (1.86)	3.02 (2.08)	2.97 (2.12)	3.01 (2.18)
Responses						
No use	12,635 (16.4)	2934 (17.0)	2081 (12.7)	1985 (14.7)	2775 (17.9)	2860 (19.6)
<1 h per day	12,043 (17.3)	3665 (24.0)	2871 (20.4)	1913 (15.4)	1987 (13.7)	1607 (12.0)
1 h per day	9718 (13.9)	2714 (17.5)	2404 (17.3)	1613 (13.0)	1602 (10.8)	1385 (10.3)
2 h per day	11,511 (16.3)	2629 (16.6)	2656 (18.4)	2050 (15.7)	2222 (15.8)	1954 (15.1)
3 h per day	9125 (12.6)	1714 (10.9)	1941 (12.7)	1776 (13.0)	1943 (13.4)	1751 (13.0)
4 h per day	5646 (7.6)	882 (5.6)	1031 (6.6)	1129 (8.4)	1392 (8.9)	1212 (8.6)
5 or more hours per day	12,264 (15.9)	1430 (8.4)	1939 (11.8)	2745 (19.8)	3150 (19.4)	3000 (21.5)
Any suicidal behavior <sup>f</sup>	14,820 (19.8)	2881 (17.1)	3030 (19.6)	2685 (20.4)	3313 (21.7)	2911 (20.5)
Specific suicidal behaviors						
Suicidal thoughts	12,031 (16.2)	2306 (13.8)	2374 (15.8)	2210 (16.9)	2720 (17.6)	2421 (17.3)
Suicide plan	9796 (13.0)	1840 (10.8)	1974 (12.8)	1831 (13.5)	2254 (14.5)	1897 (13.5)
Suicide attempt	5087 (7.5)	1027 (6.3)	1146 (7.7)	988 (7.8)	1153 (8.5)	773 (7.2)
<b>Additional covariates</b>						
School safety concern <sup>g</sup>	4572 (5.8)	906 (4.9)	975 (5.8)	999 (6.8)	924 (5.4)	768 (6.5)
Obesity <sup>h</sup>	9403 (13.4)	1855 (12.0)	1889 (12.9)	1740 (13.6)	2100 (13.9)	1819 (14.8)

<sup>a</sup> Unweighted frequency (N) and weighted percentage (%) are shown, unless otherwise specified.

<sup>b</sup> Available data (Ns = 67176–72942).

<sup>c</sup> Available data: 2009 (Ns = 14797–15968), 2011 (Ns = 13858–14923), 2013 (Ns = 12280–13211), 2015 (Ns = 13905–15071), 2017 (Ns = 11441–13769).

<sup>d</sup> Includes American Indian/Alaska Native, Native Hawaiian/Other Pacific Islander, Asian, and Multiracial/Multiethnic.

<sup>e</sup> “On an average school day, how many hours do you play video or computer games or use a computer for something that is not school work?”; None = 0, <1 h/day = 1, 1 h/day = 2, 2 h/day = 3, 3 h/day = 4, 4 h/day = 5, and ≥5 h/day = 6 (range: 0–6).

<sup>f</sup> Past 12-month report of either suicidal thought, plan, or attempt (yes/no).

<sup>g</sup> Did not go to school because of safety concerns in the past 12 months (No = 0 days; Yes = 1–6 or more days).

<sup>h</sup> ≥95<sup>th</sup> percentile for body mass index from self-report height and weight, based on sex- and age-specific 2000 CDC growth charts.

extent to which cross-year increases in the prevalence of self-reported suicidal behavior were associated with contemporaneous increases in digital media use among U.S. adolescents over 2009–2017. Secondary aims were to compare estimates by sex, given previous evidence of higher prevalences of suicidal behaviors and digital media use in females than males (Ruch et al., 2019; Shafi et al., 2019; Twenge et al., 2019a, 2018a, 2018b), and to examine whether mediation of time trends by digital media use was observed for specific suicidal behaviors (i.e., thoughts, plans, and actions).

2. Methods

2.1. Participants and study design

Data were drawn from the Youth Risk Behavior Surveillance System (YRBSS) (Kann et al., 2018), a cross-sectional, biennial Centers for Disease Control and Prevention (CDC)-led survey. This study pooled 2009, 2011, 2013, 2015, and 2017 YRBSS data. YRBSS employs a three-stage, cluster sample design yielding a nationally-representative sample of U.S. public and private high school students. Questionnaires were self-administered in classrooms on computer-scannable forms. Participation was anonymous and voluntary after obtaining parental permission per local procedures. All students in the sampled classes were eligible to participate. Over the 2009–2017 surveys, school participation rates among eligible schools ranged from 69% to 81% (Eaton et al., 2012, 2010; Kann et al.,

2014, 2016, 2018). YRBSS procedures were approved by the CDC institutional review board and are detailed elsewhere (Brener et al., 2013).

2.2. Measures

2.2.1. Suicidal behavior

At each year, the YRBSS included separate items assessing past-year suicidal ideation, plan, and attempts: “did you ever seriously consider attempting suicide?” (yes/no); “did you make a plan about how you would attempt suicide?” (yes/no), “how many times did you actually attempt suicide?” (recoded 0 vs. ≥1 attempts). The primary outcome was an any suicidal behavior binary variable distinguishing ≥1 vs. 0 affirmative responses to the 3 questions. The 3 specific suicidal behaviors responses served as secondary outcome variables (each yes/no). The suicidal behavior YRBSS items have demonstrated convergent and discriminant validity among high school students (May and Klonsky, 2011).

2.2.2. Digital media use

At each year, an item asked, “On an average school day, how many hours do you play video or computer games or use a computer for something that is not school work? (Include activities such as Xbox, PlayStation, [other example media platforms].)” Examples platforms in the question were updated each year for contemporariness (2009 [Nintendo, Game Boy, computer games, and Internet], 2011 [Nintendo DS, iPod touch, Facebook, and Internet], 2013–2015 [iPod, an iPad or other

Table 2 Associations of Survey Year, Digital Media Use,<sup>a</sup> and Suicidal Behavior and Mediation Results.<sup>b</sup>

	Bivariate associations						Adjusted cross-year difference in suicidal behavior					
	Year with suicidal behavior <sup>c</sup>		Year with digital media use <sup>d</sup>		Digital media use <sup>e</sup> with suicidal behavior <sup>c,e</sup>		Total <sup>f</sup>		Mediated by digital media use <sup>g</sup>		Proportion mediated <sup>h</sup>	
	OR	95% CI	b	95% CI	OR	95% CI	%	95% CI	%	95% CI	%	95% CI
<b>Any suicidal behavior in past 12 months<sup>i</sup></b>												
2011 vs. 2009	1.17	1.06, 1.30*	0.33	0.25, 0.40*	1.11	1.09, 1.12*	2.10	1.15, 2.99*	0.43	0.34, 0.52*	20.5	16.2, 24.8
2013 vs. 2009	1.23	1.13, 1.34*	0.70	0.55, 0.85*			2.80	1.89, 3.80*	0.96	0.69, 1.23*	34.3	24.5, 44.1
2015 vs. 2009	1.34	1.18, 1.52*	0.66	0.53, 0.78*			4.39	3.48, 5.33*	1.00	0.76, 1.23*	22.8	17.3, 28.0
2017 vs. 2009	1.19	1.01, 1.41*	0.72	0.61, 0.83*			2.60	1.69, 3.59*	1.08	0.88, 1.29*	41.4	33.9, 49.5
<b>Specific suicidal behaviors in past 12 months</b>												
<b>Suicidal thoughts</b>												
2011 vs. 2009	1.17	1.04, 1.33*	0.33	0.25, 0.40*	1.11	1.10, 1.13*	1.82	0.93, 2.64*	0.39	0.32, 0.46*	21.4	17.6, 25.8
2013 vs. 2009	1.27	1.16, 1.38*	0.70	0.55, 0.85*			2.72	1.86, 3.63*	0.85	0.61, 1.09*	31.3	22.7, 40.3
2015 vs. 2009	1.36	1.19, 1.54*	0.66	0.53, 0.78*			3.89	3.00, 4.72*	0.89	0.71, 1.06*	22.9	18.3, 27.2
2017 vs. 2009	1.25	1.07, 1.45*	0.72	0.61, 0.83*			3.01	2.13, 3.90*	1.01	0.86, 1.16*	33.6	28.7, 38.5
<b>Suicide plan</b>												
2011 vs. 2009	1.19	1.09, 1.31*	0.33	0.25, 0.40*	1.10	1.08, 1.13*	1.60	0.87, 2.42*	0.28	0.21, 0.36*	17.5	13.0, 22.6
2013 vs. 2009	1.30	1.18, 1.43*	0.70	0.55, 0.85*			2.62	1.78, 3.39*	0.68	0.43, 0.93*	26.0	16.7, 35.7
2015 vs. 2009	1.42	1.22, 1.64*	0.66	0.53, 0.78*			3.61	2.86, 4.43*	0.66	0.48, 0.84*	18.3	13.4, 23.2
2017 vs. 2009	1.25	1.04, 1.50*	0.72	0.61, 0.83*			2.19	1.47, 3.08*	0.69	0.52, 0.86*	31.5	23.7, 39.3
<b>Suicide attempt</b>												
2011 vs. 2009	1.24	1.03, 1.50*	0.33	0.25, 0.40*	1.08	1.05, 1.12*	1.09	0.53, 1.78*	0.13	0.08, 0.19*	11.9	6.9, 16.9
2013 vs. 2009	1.28	1.08, 1.51**	0.70	0.55, 0.85*			1.52	0.81, 2.12*	0.35	0.16, 0.53*	23.0	10.9, 35.1
2015 vs. 2009	1.40	1.15, 1.71*	0.66	0.53, 0.78*			2.13	1.58, 2.73*	0.33	0.20, 0.45*	15.5	9.5, 21.5
2017 vs. 2009	1.12	0.89, 1.42	0.72	0.61, 0.83*			0.41	-0.20, 1.13	0.21	0.12, 0.29*	51.8	30.0, 72.7

Abbreviations: OR, odds ratio; 95% CI, 95% confidence interval; b, unstandardized regression coefficient.

<sup>a</sup> Digital media use: “On an average school day, how many hours do you play video or computer games or use a computer for something that is not school work?”; None = 0, <1 h/day = 1, 1 h/day = 2, 2 h/day = 3, 3 h/day = 4, 4 h/day = 5, and ≥5 h/day = 6 (range: 0–6).

<sup>b</sup> Results from path analysis models adjusted for race/ethnicity, obesity, and school safety concern; separate models tested for each suicidal behavior outcome (N = 72,942).

<sup>c</sup> Logistic regression-based parameter estimate for bivariate association path from model testing total association of year with suicidal behavior (see Supplemental Fig. 1a).

<sup>d</sup> Linear regression-based parameter estimate for bivariate association path from mediation model (Supplemental Fig. 1b).

<sup>e</sup> Logistic regression-based parameter estimate for bivariate association path additionally adjusted for year from mediation model (Supplemental Fig. 1b).

<sup>f</sup> Estimated increase in suicidal behavior prevalence since 2009 adjusted for race/ethnicity, obesity, and school safety concern.

<sup>g</sup> Estimated increase in suicidal behavior prevalence since 2009 statistically mediated by concurrent increases in digital media use adjusted for race/ethnicity, obesity, and school safety concern.

<sup>h</sup> Proportion of cross-year increase in suicidal behavior prevalence vs. 2009 statistically mediated by concurrent increases in digital media use, expressed as a percentage.

<sup>i</sup> Past 12-month report of either suicidal thought, plan, or attempt (yes/no).

\* Statistically significant after Benjamini-Hochberg correction for multiple testing to control false-discovery at 0.05 (based on 2-tailed corrected P value).

tablet, smartphone, YouTube, Facebook or other social networking tools, and Internet] 2017 [iPad or other tablet, smartphone, texting, YouTube, Instagram, Facebook, or other social media]). Seven response options were coded continuously (range: 0–6; None = 0, <1 h/day = 1, 1 h/day = 2, 2 h/day = 3, 3 h/day = 4, 4 h/day = 5, and  $\geq 5$  h/day = 6).

### 2.2.3. Sex and other sociodemographics

In addition to sex (female/male), grade (9–12), race/ethnicity (African American, Hispanic, White, and Other [including American Indian/Alaska Native, Native Hawaiian/Other Pacific Islander, Asian, and Multiracial/Multiethnic, combined due to low frequencies]), and age (years;  $\geq 13$ , 14, 15, 16, 17,  $\geq 18$ ) were assessed and included for descriptive purposes.

### 2.2.4. Covariates

Every YRBSS variable assessed in each of the 2009–2017 surveys was empirically screened to determine potential for confounding and covariate inclusion. 83 variables—encompassing dietary, physical activity, sedentary, and sexual behaviors, sociodemographics, substance use, and behaviors that contribute to unintentional injury, violence, and obesity—were screened. While various factors could confound media-suicidality associations in any year, the focus of this study was on mediation of the time-suicidality association by media use. Thus, the mere association of a variable with digital media use and suicidality is not a confounder in this study if it did not also change across time. Variables met covariate inclusion criteria for this study if significant tests of association (2-tailed uncorrected  $P$  value < 0.05) were observed with the three main study variables: (1) digital media use, (2) suicidal behavior, and (3) study year, as demonstrated by increases or decreases from 2009 to each of the following years. Additionally, directions of the associations were required to be concordant with confounding for covariate inclusion: either increasing over time and positive association with digital media and suicidal behavior or decreasing over time and negative association with digital media and suicidal behavior. Race/ethnicity, obesity (based on self-reported high and weight; yes/no), and school safety concerns (“During the past 30 days, on how many days did you not go to school because you felt you would be unsafe at school or on your way to or from school?”  $\geq 1$  vs. 0 days) met each of the criteria and were included as covariates. Supplemental Table 1 lists all 83 variables’ covariate screen results.

### 2.3. Statistical analysis

After descriptive analyses, the primary analysis involved 4 sets of regression-based path models, one for each suicidal behavior outcome, each adjusted for race/ethnicity, obesity, and school safety concern, with year modeled categorically (reference = 2009). We first tested a logistic regression-based path model estimating the bivariate association of year with suicidal behavior excluding the mediator variable (see schematic in Supplemental Fig. 1a). We then tested multi-path mediation models by simultaneously including linear regression-based bivariate paths of year with digital media use and logistic regression-based bivariate paths of digital media use with suicidal behavior adjusted by year (Supplemental Fig. 1b). The component bivariate path estimates in the mediation models were used to calculate indirect “mediated” (i.e.,  $b$ -statistic) association estimates, which were translated to estimated change in suicidal behavior prevalence across years mediated by concurrent digital media use changes. To test sex differences, each association was re-tested in subsamples stratified by sex and compared using  $\chi^2$  difference tests for goodness of fit from multi-group analysis. Analysis used Mplus version 8 (Muthén and Muthén, 2017) with the complex design option to account for the YRBSS’s complex sampling and sampling weights to approximate US Census demographics. Results are reported as unstandardized regression coefficients (Bs) or odds ratios (ORs) with 95% CIs. Only cases with complete suicidal behavior and digital media data were included in the analysis. Covariate missing data

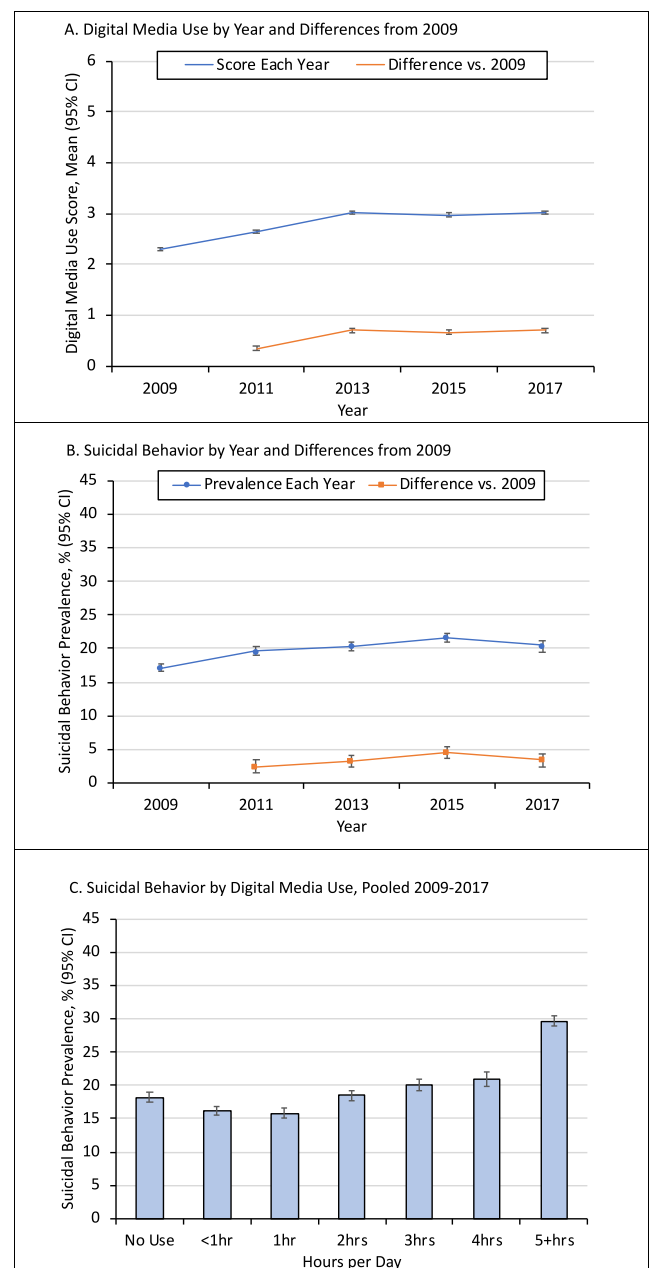


Fig. 1. Descriptive statistics of digital media use and any suicidal behavior, 2009–2017.

were managed with full information maximum likelihood estimation (see Table 1 note for available covariate data across years) (Enders, 2010). Statistical significance was  $P < 0.05$  (2-tailed). Benjamini-Hochberg corrections for multiple testing were applied to the primary analysis (Benjamini and Hochberg, 1995).

## 3. Results

### 3.1. Descriptive results

Pooled across 2009–2017, a total of 75,807 adolescents participated in the YRBSS (student response rates range: 80.6% to 88.6% across years). Of 2009–2017 YRBSS respondents, 72,942 (96.2%) had complete data for digital media use and suicidal behavior variables and constituted the study’s analytic sample (available data by year detailed in Supplemental Fig. 2). The pooled 2009–2017 sample was 49.3%

**Table 3**  
Associations of Year, Digital Media Use,<sup>a</sup> and Suicidal Behavior<sup>b</sup> and Mediation Results, by Sex.<sup>c</sup>

	Females			Males			Test of sex difference, <sup>h</sup> P Value
	Estimate	95% CI	P Value	Estimate	95% CI	P Value	
Association of year with suicidal behavior, OR (95% CI) <sup>d</sup>							
2011 vs. 2009	1.09	0.96, 1.24	0.17	1.27	1.11, 1.44	<0.001*	0.43
2013 vs. 2009	1.24	1.14, 1.36	<0.001*	1.16	1.01, 1.33	0.04*	0.76
2015 vs. 2009	1.41	1.20, 1.66	<0.001*	1.23	1.04, 1.45	0.02*	0.39
2017 vs. 2009	1.23	0.98, 1.54	0.07	1.08	0.88, 1.32	0.46	0.48
Association of year with digital media use, b (95% CI) <sup>e</sup>							
2011 vs. 2009	0.36	0.27, 0.46	<0.001*	0.29	0.20, 0.40	<0.001*	0.16
2013 vs. 2009	0.89	0.72, 1.06	<0.001*	0.54	0.37, 0.71	<0.001*	0.01*
2015 vs. 2009	0.88	0.68, 1.07	<0.001*	0.47	0.34, 0.59	<0.001*	0.005*
2017 vs. 2009	0.89	0.72, 1.06	<0.001*	0.59	0.45, 0.73	<0.001*	0.01*
Association of suicidal behavior with digital media use, OR (95% CI) <sup>f</sup>							
Pooled, 2009–2017	1.12	1.10, 1.14	<0.001*	1.11	1.09, 1.14	<0.001*	0.91
Cross-year difference in suicidal behavior mediated by digital media use, % (95% CI) <sup>g</sup>							
2011 vs. 2009	0.61	0.44, 0.79	<0.001*	0.33	0.21, 0.50	<0.001*	0.14
2013 vs. 2009	1.56	1.24, 1.90	<0.001*	0.67	0.36, 0.99	<0.001*	0.03*
2015 vs. 2009	1.70	1.38, 2.02	<0.001*	0.63	0.34, 0.91	<0.001*	0.02*
2017 vs. 2009	1.76	1.43, 2.11	<0.001*	0.38	0.26, 0.51	<0.001*	0.02*

Abbreviations: OR, odds ratio; 95% CI, 95% confidence interval; b, unstandardized regression coefficient.

<sup>a</sup> Digital media use: "On an average school day, how many hours do you play video or computer games or use a computer for something that is not school work?" - None = 0, <1 h/day = 1, 1 h/day = 2, 2 h/day = 3, 3 h/day = 4, 4 h/day = 5, and ≥5 h/day = 6 (range: 0–6).

<sup>b</sup> Past 12-month report of either suicidal thought, plan, or attempt (yes/no).

<sup>c</sup> Results from path analysis models adjusted for obesity, school safety concern, and race/ethnicity tested separately in females (N = 36,726) and males (N = 35,877).

<sup>d</sup> Logistic regression-based parameter estimate for bivariate association path for model testing total association of year with suicidal behavior (see Supplemental Fig. 1a).

<sup>e</sup> Linear regression-based parameter estimate for bivariate association path.

<sup>f</sup> Logistic regression-based parameter estimate for bivariate association path additionally adjusted for year from mediation model (Supplemental Fig. 1b).

<sup>g</sup> Covariate-adjusted estimated increase in suicidal behavior prevalence since 2009 statistically mediated by concurrent increases in digital media use.

<sup>h</sup> Calculated by chi-squared goodness of fit test.

\* Statistically significant after Benjamini-Hochberg correction for multiple testing to control false-discovery at 0.05 (based on 2-tailed corrected P value).

female, 13.7% African American, 20.7% Hispanic, 9.2% other race/ethnicity, 56.4% white, and were fairly evenly distributed across ages and grades. The mean digital media frequency score pooled from 2009 to 2017 was 2.78 (SD = 2.03), sitting in between the 2-point (1-hour/day media use) and 3-point (2-hour/day) response options. Collapsed across 2009–2017, 19.8% reported ≥1 types of past-year suicidal behavior, with 16.2%, 13.0%, and 7.5% reporting past-year suicide thoughts, plans, and attempts, respectively. Table 1 depicts descriptive statistics of all study variables, pooled and by survey year.

### 3.2. Primary results

After covariate adjustment, self-reported suicidal behavior prevalence in 2011 (19.6%, OR[95%CI] = 1.17[1.06, 1.30]), 2013 (20.4%, adjusted-OR[95%CI] = 1.23[1.13, 1.34]), 2015 (21.7%, OR[95%CI] = 1.34[1.18, 1.52]), and 2017 (20.5%, adjusted-OR[95%CI] = 1.19[1.01, 1.41]) were each significantly higher than the 2009 (17.1%) estimate (Table 2, Fig. 1A). Self-reported digital media use frequency on the 6-point scale in 2011 (Mean[SD] = 2.65[1.86], b[95%CI] = 0.33[0.25, 0.40]), 2013 (Mean[SD] = 3.02[2.08], b[95%CI] = 0.70[0.55, 0.85]), 2015 (Mean[SD] = 2.97[2.12], b[95%CI] = 0.66[0.53, 0.78]), and 2017 (Mean[SD] = 3.01[2.18], b[95%CI] = 0.72[0.61, 0.83]) were each significantly higher than 2009 (Mean[SD] = 2.31[1.81]) estimate (Table 2, Fig. 1B) after covariate adjustment. Adjusted for year and other covariates, each 1 point higher on the 0–6 digital media frequency scale was associated with 1.11(95%CI = 1.09, 1.12) greater odds of any suicidal behavior pooled across 2009–2017 (Table 2, Fig. 1C). Given this 1.1 association on the continuous media scale, there is a 1.9 difference in odds between a low (<1hr/day; score = 1) and high (5 + hr/day; score = 6) use of digital media.

Increases in suicidal behavior from 2009 to 2017 were significantly mediated by concurrent increases in digital media use (Table 2). The

total covariate-adjusted estimated cross-year difference in suicidal behavior prevalence was 2.10%(95%CI = 1.15, 2.99) for the 2011 vs. 2009 change, 2.80%(95%CI = 1.89, 3.80) for 2013 vs. 2009, 4.39%(95%CI = 3.48, 5.33) for 2015 vs. 2009, and 2.60%(95%CI = 1.69, 3.59) for 2017 vs. 2009. The cross-year difference in suicidal behavior prevalence statistically mediated by digital media use was 0.43%(95%CI = 0.34, 0.52; indirect b = 0.033[95%CI = 0.026, 0.040]) for the 2009 vs. 2011 change, 0.96%(95%CI = 0.69, 1.23; indirect b = 0.070[95%CI = 0.050, 0.091]) for 2009 vs. 2013, 1.00%(95%CI = 0.76, 1.23; indirect b = 0.066[95%CI = 0.050, 0.081]) for 2009 vs. 2015, and 1.08%(95%CI = 0.88, 1.29; indirect b = 0.072[95%CI = 0.059, 0.086]) for 2009 vs. 2017. These mediation estimates represent 20.5%(95%CI = 16.2, 24.8), 34.3%(95%CI = 24.5, 44.1), 22.8%(95%CI = 17.3, 28.0), and 41.4%(95%CI = 33.9, 49.5) of the total adjusted cross-year increases in suicidal behavior prevalence from 2009 to 2011, 2013, 2015, and 2017, respectively (Table 2). Estimated cross-year changes in suicidal behavior not mediated by digital media use are reported in Supplemental Table 2.

### 3.3. Secondary results

#### 3.3.1. Specific suicidal behaviors

Table 2 and Supplemental Fig. 3 depict analyses of specific suicidal behavior outcomes. Increases in suicide thoughts, plans, and attempts across years were each significantly mediated by concurrent increases in digital media use. Each bivariate positive association between year, digital media use, and specific suicidal behaviors were statistically significant, with the exception of the 2017 vs. 2009 change in suicide attempts which was significant in unadjusted (difference[95%CI] = 0.94% [0.31, 1.58]) but not covariate-adjusted (difference[95%CI] = 0.41% [-0.20, 1.13]) analyses.

### 3.3.2. Any suicidal behavior stratified by sex

Increases in any suicidal behavior were significantly mediated by concurrent increases in digital media use for each cross-year comparison vs. 2009 in both sexes (Table 3). The magnitude of cross-year difference in suicidal behavior prevalence mediated through digital media use was significantly stronger in females compared to males for the 2009 to 2013, 2015, and 2017 changes but did not significantly differ by sex for the 2009 to 2011 change. The component bivariate association estimates indicate that although there were significant cross-year increases in digital media use frequency for both sexes, the magnitude of increase was significantly higher in females than males for 2009 vs. 2013, 2009 vs. 2015, and 2009 vs. 2017 contrasts, but not the 2009 to 2011 contrast. Digital media use frequency was significantly associated with higher suicidal behavior odds, pooled across years, in both females and males and these associations did not significantly differ by sex (see Fig. 2).

### 3.4. Sensitivity analysis

Sensitivity analyses found statistically significant mediation estimates in models that omitted covariates (Supplemental Table 3) and in those that limited data to 2011–2017 survey years with 2011 as a referent (Supplemental Table 4).

## 4. Discussion

By using mediation analysis of multi-year person-level data from 2009 to 2017, the current study found that increasing digital media use trends were associated with concurrent increasing trends in suicidal thoughts, plans, and attempts in U.S. youth. The magnitude of this association was small, such that increasing digital media use statistically accounted for less than half of the changing prevalence over time in suicidal behavior. Aggregated across years, the overall adjusted association between digital media use and suicidal behavior was subtle, such that clinically-significant moderate-sized differences in risk for an individual are not observed until contrasting between high and low use of digital media. On balance, the results indicate that digital media use and suicidal behavior trends may be connected, but there are likely other factors that may be independently contributing to increasing media use and increasing suicidality in youth this decade.

Previous studies of digital media use and adolescent suicidal behavior separate into two distinct research threads: (1) observational evidence of digital media use-suicidal behavior associations (Odgers and Jensen, 2020; Orben and Przybylski, 2019; Shafi et al., 2019; Twenge and Campbell, 2019), and (2) ecological evidence of increasing digital media use and suicidal behavior trends (Twenge et al., 2019a, 2018a, 2018b). Prior separation of these threads precluded empirically-supported conclusions regarding any role digital media use and suicidal behavior might be playing in one another, given the possibility that ecological time series or other trend analyses utilizing population aggregate data are vulnerable to ecological fallacy effects. The current results considered in the context of extant literature indicates that at both the person-level and the population-level, media use and suicidality trends may be associated to some degree. In this study, digital media use did not explain a majority of the increase in suicidal behavior over 2009–2017, which suggests that there may be several factors that independently contribute to recent upward trends in suicidal behavior and media use among adolescents.

There are several explanations for these results, including confounding. Because survey year was the independent variable in this study, shared determinants of both digital media use and suicidal behavior that might be responsible for their bivariate association could not confound the mediation results unless those factors changed from 2009 to 2017. To address possible confounding, 83 YRBSS variables were empirically screened as possible covariates, 3 of which were identified as possible confounders and adjusted for in analyses, including race/ethnicity, obesity, and concern about being safe at school. It remains possible that other unaddressed confounders not measured in YRBSS might have influenced both digital media use and suicidal behavior as well as changed over 2009–2017. For example, fallout from the opioid epidemic, rising social or economic inequality, political and economic instability, and increased school surveillance could have contributed (Bachman et al., 2011; Brent et al., 2019; Elgar et al., 2015; Williams and Medlock, 2017). Adolescents experiencing parental overdose-related death or social or economic hardships this decade may have less parental oversight and greater opportunity to use digital media unsupervised. The same factors could also contribute to rising stress and suicidal behavior. Because this study was cross-sectional, directionality cannot be determined. Suicidal behavior was analyzed as a dependent (rather than exposure) variable because of its significance as a health outcome, but it could very well affect digital media use. Teens in distress might turn to digital media as a means to cope with stress, a distraction, or a way to reach out to peers on social

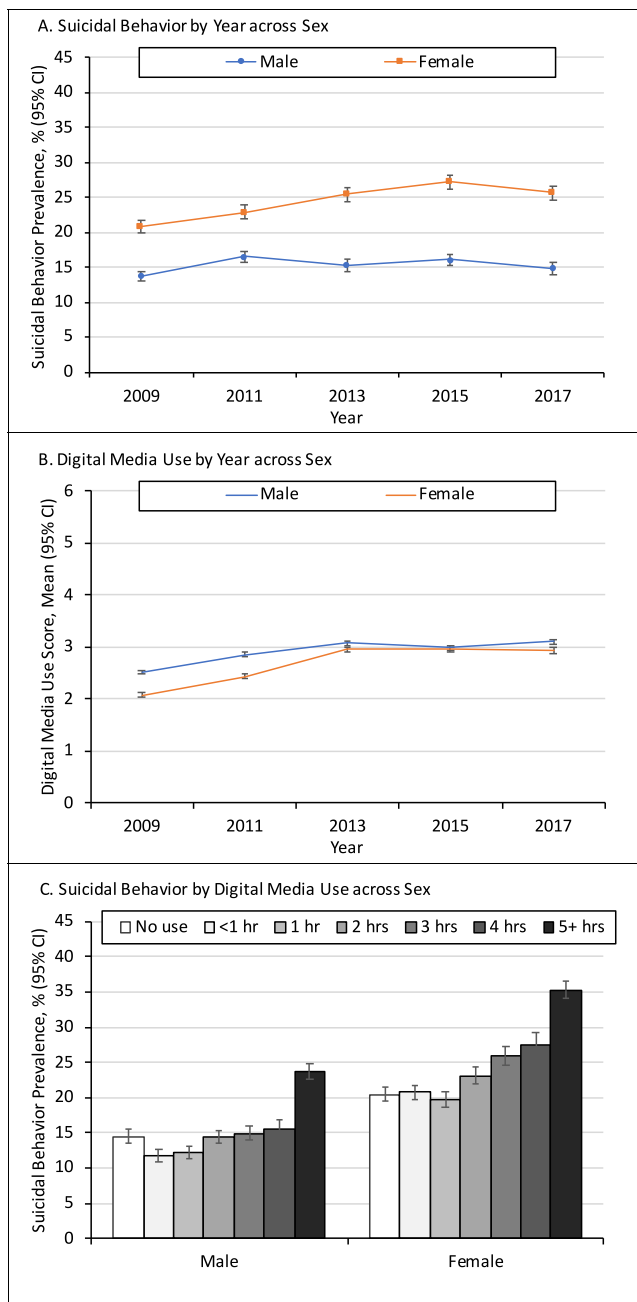


Fig. 2. Descriptive statistics of digital media use and any suicidal behavior by sex.

media (Ali et al., 2015); this may be especially true for teens with marginalized social status for which finding peers online is a common source of social support (Ybarra et al., 2015).

Although research suggests a modest inverse relation of digital media use with wellbeing in the overall youth population (Orben and Przybylski, 2019; Twenge and Campbell, 2019), the association is complex, likely varies across context and individuals, and could be protective in some circumstances while harmful in others (Odgers and Jensen, 2020). For some adolescents, digital media use may improve wellbeing by increasing social connections, accessing information, and providing a recreational outlet (Chassiakos et al., 2016). In other cases, frequent digital media use might increase odds of exposure to cyberbullying, idealized depictions of social lifestyles that are difficult to live up to, distressing content, or unhealthy interpersonal relationships that worsen mental health (Vidal et al., 2020). Excessive digital media use might also displace opportunity for exercise or other wellbeing-enhancing experiences (Shimoga et al., 2019).

Dosage of digital media might be one source of heterogeneity in the association of media use with suicidal behavior (Twenge and Campbell, 2019). In this study, elevated prevalence of suicidal behavior was not observed until teens surpassed 1 h per day and was most pronounced in teens spending 5+ hours every weekday using digital media entertainment. Sex may be another source of heterogeneity, as this study found that the increase in suicidal behavior mediated concurrent increases in digital media over time was higher in females than males. The likelihood that this finding is explained by digital media use being more harmful to females than males is low because the digital media use-suicidal behavior association did not differ by sex in this study. Rather, it is more likely that this finding reflects that level digital media use exposure accelerated more quickly after 2011 in females than males, which is consistent with recent research indicating that female youth tend to use certain forms of digital media, such as social media, more frequently than male youth (Twenge et al., 2019b).

## 5. Limitations

First, the cross-sectional correlational study design precludes causal inferences and unmeasured confounding cannot be ruled out. Second, the YRBSS items may have demand characteristics that therefore make it susceptible to response bias and mischievous responding issues. Third, subtypes of digital media (i.e., videogames vs. social media, etc.) and content domains are not distinguished in the YRBSS single-item measure, yet different digital media platforms may have distinct associations with wellbeing (Houghton et al., 2018). Future studies should investigate digital media use-suicidality associations by leveraging more nuanced measures of digital media use and content to better understand how distinct digital media behaviors may have differential associations with suicidality. Fourth, the YRBSS digital media measure wording varied across years to accommodate changes in platforms used by youth (e.g., Instagram did not exist in 2009 but later became a leading application used by youth and was incorporated into the 2017 YRBSS) (Anderson and Jiang, 2018). While these updates likely increase the measure's ecological validity, they might also introduce cross-year differences in psychometric properties that could have affected the findings. Fifth, there may be non-linear associations between digital media use frequency and suicidal behavior (Twenge and Campbell, 2019) that mediation analysis is not well-suited to address. Future research should consider modeling associations as non-linear functions, such as ones that are quadratic in nature (Scherr, 2018). Finally, there is a need for panel/longitudinal data collected among multiple historically distinct cohorts to analyze both person-level intra-individual changes and cohort-level between-person changes to understand optimally how trends in exposure to media use and suicidal behavior across time might be causally connected.

## 6. Conclusions

In summary, small proportions of the 2009–2017 increases in U.S. adolescent suicidal behavior were associated with concurrent increasing digital media use trends. Further research is needed to assess the reasons why increasing media use and suicidal behavior trends are associated with one another to best inform policy and public health practice.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.pmedr.2021.101497>.

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