

https://dspace.org/

# Prospective association between screen use modalities and substance use experimentation in early adolescents

**J Nagata; J Shim; P Low; K Ganson; Fiona Baker ...**

https://hdl.handle.net/10539/46217
WOS

Downloaded from a DSpace repository. https://dspace.org/

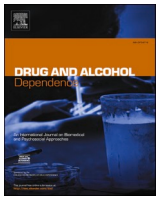
Drug and Alcohol Dependence 266 (2025) 112504



Contents lists available at ScienceDirect

Drug and Alcohol Dependence

journal homepage: www.elsevier.com/locate/drugalcdep





# Prospective association between screen use modalities and substance use experimentation in early adolescents

Jason M. Nagata [a,*], Joan Shim [a], Patrick Low [a], Kyle T. Ganson [b], Alexander Testa [c], Jinbo He [d], Glenn-Milo Santos [e], Claire D. Brindis [a,f], Fiona C. Baker [g,h], Iris Y. Shao [a]

[a] Division of Adolescent and Young Adult Medicine, Department of Pediatrics, University of California, San Francisco, 550 16th Street, Box 0503, San Francisco, CA 94143, USA
[b] Factor-Inwentash Faculty of Social Work, University of Toronto, 246 Bloor St W, Toronto, ON M5S 1V4, Canada
[c] Department of Management, Policy and Community Health, University of Texas Health Science Center at Houston, 7000 Fannin St, Houston, TX 77030, USA
[d] Division of Applied Psychology, School of Humanities and Social Science, The Chinese University of Hong Kong, 2001 Longxiang Boulevard, Longgang District, Shenzhen 518172, China
[e] Department of Community Health Systems, School of Nursing, University of California, San Francisco, 2 Koret Way, San Francisco, CA 94143, USA
[f] Philip R. Lee Institute for Health Policy Studies, University of California, San Francisco, 490 Illinois St, San Francisco, CA 94158, USA
[g] Center for Health Sciences, SRI International, Menlo Park, Menlo Park, 333 Ravenswood Ave, Menlo Park, CA 94025, USA
[h] School of Physiology, University of the Witwatersrand, 1 Jan Smuts Ave, Braamfontein, Johannesburg 2017, South Africa

ARTICLE INFO

*Keywords:*
Digital media
Social media
Technology
Adolescent
Substance use
Alcohol
Tobacco
Marijuana

ABSTRACT

*Background:* There are limited large-scale, prospective analyses examining contemporary screen use and substance use experimentation in early adolescents. The current study aimed to determine associations between eight forms of contemporary screen modalities and substance use experimentation one year later in a national cohort of 11–12-year-olds in the United States.

*Methods:* The sample consisted of 8006 early adolescents (47.9 % female and 41.6 % racial/ethnic minority) from the prospective cohort data of the Adolescent Brain Cognitive Development (ABCD) Study. Logistic regression analyses were conducted to evaluate the prospective associations between screen time (eight different types and total) in Year 2 and substance use experimentation (alcohol, nicotine, cannabis, any substance use) in Year 3, adjusting for covariates and Year 2 substance use experimentation.

*Results:* Total screen time was prospectively associated with alcohol, nicotine, and cannabis experimentation. Each additional hour spent on social media (AOR 1.20; 95 % CI 1.14–1.26), texting (AOR 1.18; 95 % CI 1.12–1.24), and video chatting (AOR 1.09; 95 % CI 1.03–1.16) was associated with higher odds of any substance experimentation. Social media use and texting were also associated with higher odds of alcohol, cannabis, and nicotine experimentation; however, television/movies, videos, video games, and the internet were not. Moreover, video chatting was associated with higher odds of cannabis and nicotine experimentation.

*Conclusions:* Our findings indicate that digital social connections, such as via social media, texting, and video chatting, are the contemporary screen modalities that are associated with early adolescent substance experimentation. Future research could explore the mechanisms underlying these associations to inform intervention strategies.

## 1. Introduction

Substance use is a significant public health concern in the United States. In adolescents, previous literature has found that substance use may be associated with multiple adverse outcomes, including poor academic performance, cognitive impairment, increased risk-taking behaviors, and interference with personal relationships later in life (Broyd et al., 2016; Nelson et al., 2015; Welty et al., 2017). Additionally, substance use experimentation in early adolescence has been linked to the development of substance use disorders later in life (Moss et al.,

*Abbreviations:* ABCD, Adolescent Brain Cognitive Development Study.

* Correspondence to: 550 16th Street, 4th Floor, Box 0503, San Francisco, California 94143, USA.
*E-mail address:* jason.nagata@ucsf.edu (J.M. Nagata).

https://doi.org/10.1016/j.drugalcdep.2024.112504
Received 29 August 2024; Received in revised form 5 November 2024; Accepted 9 November 2024
Available online 14 November 2024
0376-8716/© 2024 The Author(s). Published by Elsevier B.V. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/).

2014). Despite this, intervention during the early stages of substance use may reduce its severity and persistence (de Girolamo et al., 2012). Therefore, the identification of risk factors for substance use is a high priority to help inform targeted interventions aimed at reducing substance use in early adolescence.

Screen use has emerged as a prominent factor influencing multiple health and behavioral outcomes in adolescents. Sequelae associated with screen use in adolescents include depressive symptoms, anxiety, decreased physical activity, and obesity (Santos et al., 2023; Stiglic and Viner, 2019). Additionally, several investigations have previously detailed the relationship between screen use and substance use in adolescents (Hull et al., 2014; Ko et al., 2008; Rücker et al., 2015). Kelleghan and colleagues, in their longitudinal investigation, found that certain forms of screen use, including social media and texting, increased the odds of tobacco and cannabis initiation in high school-aged adolescents 14–18 years old (Kelleghan et al., 2020). Moreover, alcohol and tobacco content depicted in media was associated with alcohol and tobacco use in a cross-sectional investigation of adolescents from the United Kingdom, suggesting a potential role of media in promoting these behaviors in this population (Cranwell et al., 2016). Peer influence has long been established as a potential predictor of substance use in adolescents, and exposure to substance-related content on social media platforms may further normalize and promote these behaviors, influencing adolescents' attitudes towards substance use, which may ultimately lead to substance use experimentation (Jackson et al., 2018; Schuler et al., 2019).

The period of early adolescence may be a particularly important window in which adolescents are susceptible to the impacts of screen time on substance use. Life Course Theory posits that experiences during key developmental stages, such as early adolescence, can significantly shape long-term behavioral outcomes (Hutchison, 2017). This period is marked by heightened brain plasticity, social transitions, and increased vulnerability to external influences in which exposure to risk factors such as screen use may disrupt developmental trajectories and heighten the likelihood of substance experimentation later in life (Fandakova and Hartley, 2020; Gil et al., 2004; Jordan and Andersen, 2017). In addition, Social Influence Theory emphasizes the role of social environments in shaping behaviors, and adolescents' interactions with media may reinforce substance use behaviors through social mechanisms such as peer influence and normalization of behaviors (Kelman and Tedeshi, 1974; Orben et al., 2022; Simons-Morton, 2007).

Despite this theoretical basis, there are still notable gaps in the literature documenting the association between screen use and substance use behaviors during the period of early adolescence. Additionally, the majority of prior investigations implemented cross-sectional designs, which are limited in their ability to determine temporality in relationships. The present investigation aimed to assess the prospective association between screen use, considering multiple contemporary modalities, and substance use experimentation in a demographically diverse, national sample of early adolescents in the United States. We hypothesized that screen use would be associated with subsequent substance experimentation in early adolescents.

## 2. Materials and methods

### 2.1. Study population

This prospective analysis utilized data from the Year 2 and Year 3 follow-up of the Adolescent Brain Cognitive Development (ABCD) Study. The ABCD Study is the largest long-term longitudinal study of adolescent health, brain, and cognitive development in the U.S., and it recruited 11,875 children from 21 sites in 2016–2018 (baseline). The ABCD Study sample, recruitment, protocol, and measures have been previously described in detail (Barch et al., 2021; Dick et al., 2021; Garavan et al., 2018). Participants were primarily recruited through public and private schools, and procedures to reduce selection bias from school selection were implemented (Garavan et al., 2018). Participants were mostly 11–12 years old during the Year 2 follow-up (2018–2020). The analytic sample here included 8006 participants with complete screen time, substance use experimentation, and covariate data. Appendix A compares participants who were included and excluded from this study. Centralized institutional review board approval was received from the University of California, San Diego. Written assent was obtained from the study participants, and written consent was obtained from their parents/guardians.

### 2.2. Screen time use

The ABCD Youth Screen Time Survey in Year 2 was used to determine screen time use among participants (Bagot et al., 2022). Participants were asked about their average daily screen time use for both weekdays and weekends on different screen modalities, including 1) watching TV shows or movies, 2) watching videos (e.g., YouTube), 3) playing single-player video games, 4) multi-player video games, 5) texting, 6) video chatting (e.g., Skype, Facetime), 7) social media (e.g., Facebook, Instagram, Twitter), and 8) internet (e.g., Google). For each screen modality, the time spent on weekdays and weekends was weighted and summed in the equation ((weekday average $\times$ 5) + (weekend average $\times$ 2))/7) to calculate the average hours per day spent on each screen modality and account for different screen time averages on weekdays and weekends (Guerrero et al., 2019). The sum of the eight screen modalities was taken to create the average total recreational screen time of each study participant. The self-reported screen time measure was significantly positively correlated ($r=0.49$, $p<0.001$) with passive, objectively sensed smartphone use in the ABCD Study (Wade et al., 2021). Similarly, prior studies of self-reported social media found acceptable convergent validity ($r=0.55$–$0.65$) with experience sampling methodology measures of social media (Verbeij et al., 2021).

### 2.3. Substance use experimentation

The ABCD Study assessed low-level use of alcohol, nicotine, and cannabis (Lisdahl et al., 2018). Study participants were given this survey in both Years 2 and 3 and were asked if they had a sip of alcohol such as beer, wine, or liquor (rum, vodka, gin, whiskey); a puff from a tobacco or electronic cigarette, Juul, vape pens, e-hookah, cigar or pipe; a puff or eaten any marijuana, also called pot, grass, weed or ganja. Any substance use experimentation was defined as having tried any of the three substances (e.g., a sip of alcohol, a puff of a nicotine product, or a puff of cannabis) as has been previously analyzed and reported (Sullivan et al., 2022). The alcohol sipping measure was adapted from the iSay Sip Inventory, an 8-item measure of recent alcohol sipping that characterizes the adolescent's first alcohol-sipping experience (Jackson et al., 2015).

### 2.4. Covariates

Age, sex (female or male), race and ethnicity (non-Latino/Hispanic White, Latino/Hispanic of any race, non-Latino/Hispanic Black, non-Latino/Hispanic Asian/Pacific Islander, non-Latino/Hispanic Native American, and non-Latino/Hispanic Other), household income, and parent's highest level of education were self-reported by participants or their caregivers. Household income had six categories: $24,999 or less; $25,000 to $49,999; $50,000 to $74,999; $75,000 to $99,999; $100,000 to $199,999; and $200,000 and greater. Highest parent education was categorized into "high school education or less" or "college education or higher." All covariates were recorded at baseline (Year 0) except age and household income, which were recorded at the Year 2 follow-up. The Family Environment Scale was used to assess youth-reported family conflict at baseline, which was calculated by taking the average of nine questions evaluating conflict between family members (parents and children) (Gonzalez et al., 2021; Moos and Moos, 1976; Zucker et al., 2018). A higher family conflict score (ranging from 0 to 9) indicates

greater family conflict, and this score was shown to have good test-retest reliability (ICC = 0.49) and internal validity (α= 0.68) (Gonzalez et al., 2021; Taber, 2018). The Child Opportunity Index (COI) 2.0 uses 29 neighborhood indicators to compute an index of neighborhood resource availability relevant to healthy child development (Acevedo-Garcia et al., 2020). COI scores ranged from 1 to 100, with higher scores representing greater available resources, which were transformed into z-scores and adjusted to reflect national norms (Acevedo-Garcia et al., 2020). Substance experimentation in Year 2 was also included as a covariate.

### 2.5. Statistical analysis

We performed our analysis using Stata 18 (StataCorp, College Station, TX). The mean, standard deviation (SD), and percentages of variables were used to calculate descriptive statistics. Multiple logistic regression models were used to estimate the associations between screen time modalities in Year 2 and substance use experimentation in Year 3, adjusting for covariates and substance use experimentation in Year 2. We also tested for moderation by sex and race and ethnicity on the association between screen time and substance use experimentation. We applied the ABCD Study sampling weights based on the American Community Survey from the U.S. Census. To account for multiple statistical tests, the Benjamini-Hochberg procedure was used to adjust for a false discovery rate (Benjamini and Hochberg, 1995).

## 3. Results

The sociodemographic characteristics of the 8006 participants included in this study are presented in Table 1. Study participants had an average age of 12.1 (SD=0.7) years old at Year 2. Around half of the participants were female (47.9 %), and 41.6 % were from racial and ethnic minority groups. A little over half of the participants (53 %) had a family household income of less than $75,000, and most participants (85.2 %) had parents with a college education or higher. Adolescents reported spending an average of 7.5 hours per day (SD=7.9) on total recreational screen time. The average time spent texting and on social media were both 0.7 hours per day, and study participants spent an average of 0.5 hours per day video chatting.

**Table 1**
Sociodemographic and screen time characteristics of Adolescent Brain Cognitive Development (ABCD) Study participants (N=8006).

| Sociodemographic and screen time characteristics | Mean (SD) / % |
|---|---|
| Age at Year 2 (years, mean (SD)) | 12.1 (0.7) |
| Sex (%) | |
| Female | 47.9 % |
| Male | 52.1 % |
| Race and ethnicity (%) | |
| White | 58.4 % |
| Latino / Hispanic | 18.3 % |
| Black | 13.7 % |
| Asian | 5.1 % |
| Native American | 3.2 % |
| Other | 1.3 % |
| Household income (%) | |
| $24,999 or less | 14.7 % |
| $25,000 to $49,999 | 20.1 % |
| $50,000 to $74,999 | 18.3 % |
| $75,000 to $99,999 | 14.3 % |
| $100,000 to $199,999 | 24.6 % |
| $200,000 and greater | 8.1 % |
| Parents' highest education (%) | |
| High school education or less | 14.8 % |
| College education or more | 85.2 % |
| Screen time at Year 2 (hours per day, mean (SD)) | |
| Total recreational screen time | 7.5 (7.9) |
| Television shows / movies | 1.6 (1.8) |
| Videos | 1.5 (1.9) |
| Video games (single-player) | 1.0 (1.6) |
| Video games (multi-player) | 1.1 (1.8) |
| Texting | 0.7 (1.5) |
| Social media | 0.7 (1.6) |
| Video chat | 0.5 (1.3) |
| Internet | 0.4 (0.7) |

ABCD sampling weights were applied based on the American Community Survey from the US Census. SD = standard deviation.

Overall, there was an increase in substance use experimentation among study participants from Year 2 to Year 3 (Table 2). Alcohol use was the most prevalent substance used among participants. Among participants who reported any substance use, 51.6 % were male and 69.8 % were White (not shown in Table 2).

The prospective associations between screen time and substance use experimentation are shown in Fig. 1. In general, total recreational screen time was prospectively associated with alcohol, nicotine, cannabis, and overall substance use experimentation. Each additional hour spent texting per day was associated with a 1.18 (95 % CI:1.12–1.24) times higher odds of experimenting with substances in the following year. More specifically, each additional hour spent texting per day in Year 2 was associated with 1.14 (95 % CI:1.08–1.20) times higher odds of experimenting with alcohol, 1.16 (95 % CI:1.06–1.26) times higher odds of experimenting with nicotine, and 1.18 (95 % CI:1.08–1.29) times higher odds of experimenting with cannabis in Year 3. Similar effect sizes were found for social media use. Each additional hour spent on social media per day was prospectively associated with 1.20 (95 % CI:1.14–1.26) times higher odds of experimenting with substances. For each additional hour spent on social media per day in Year 2, there was a 1.15 (95 % CI:1.10–1.21) times higher odds of experimenting with alcohol, 1.23 (95 % CI:1.14–1.32) times higher odds of experimenting with nicotine, and 1.22 (95 % CI:1.13–1.33) times higher odds of experimenting with cannabis in Year 3. An additional hour spent video chatting per day was associated with a 1.09 (95 % CI:1.03–1.16) times higher odds of substance use, a 1.14 (95 % CI:1.07–1.22) times higher odds of experimenting with nicotine, and 1.13 (95 % CI:1.03–1.24) times higher odds of cannabis use in the following year. There were no significant associations between five screen modalities (television shows/movies, videos, single-player video games, multi-player video games, and internet) and substance use experimentation. There was no evidence of effect modification of screen time by sex or race and ethnicity for any of the substance use experimentation outcomes.

## 4. Discussion

In this prospective analysis of a demographically diverse sample of early adolescents in the United States, we found that total screen time and three different forms of screen use were associated with substance use. Notably, social media use and text messaging were both associated with higher odds of alcohol, cannabis, and nicotine experimentation. Additionally, video calling was associated with higher odds of cannabis and nicotine experimentation. These findings suggest that modalities relating to digital social connections (e.g., social media, text messaging, and video calling) may be primarily driving the relationship between

**Table 2**
Substance use experimentation in the Adolescent Brain Cognitive Development (ABCD) Study (N=8006).

| | Year 2 | Year 3 |
|---|---|---|
| Have tried a sip of a sip of alcohol such as beer, wine or liquor (rum, vodka, gin, whiskey)? | 10.4 % | 12.0 % |
| Have tried a puff from a tobacco or electronic cigarette, Juul, vape pens, e-hookah, cigar or pipe? | 1.0 % | 2.5 % |
| Have tried a puff or eaten any marijuana, also called pot, grass, weed or ganja? | 0.3 % | 1.0 % |
| Any substance use experimentation | 11.1 % | 13.2 % |

ABCD sampling weights were applied based on the American Community Survey from the US Census.

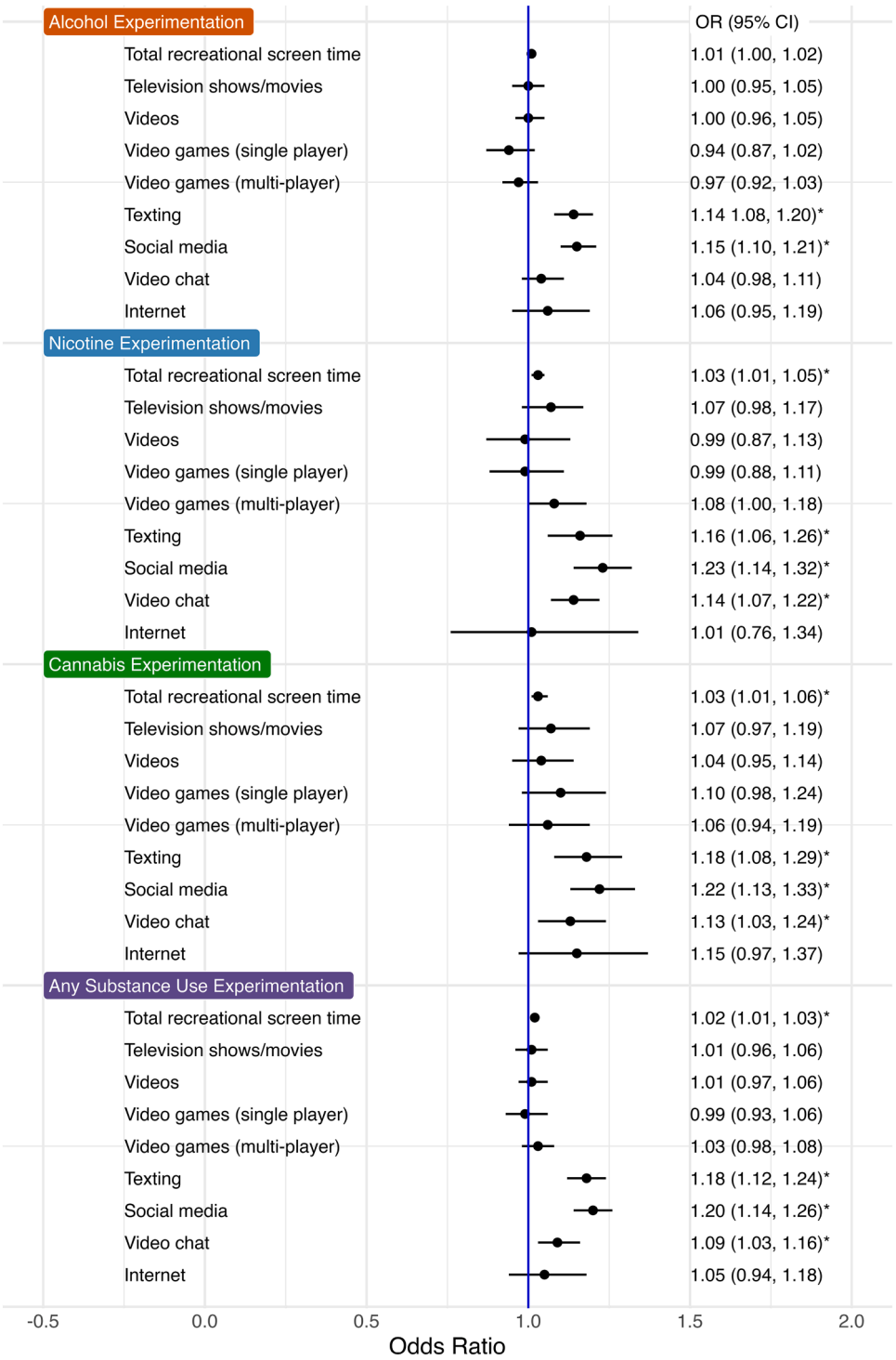



**Fig. 1.** Associations between screen time and substance use experimentation in the Adolescent Brain Cognitive Development (ABCD) Study. * indicates statistical significance after the Benjamini-Hochberg procedure. OR=odds ratio from logistic regression model. Models represent the abbreviated output from the logistic regression models, including adjustment for age, sex, race and ethnicity, household income, parent education, family conflict, Child Opportunity Index score, study site, and the respective substance use experimentation variable at Year 2. Sampling weights from the Adolescent Brain Cognitive Development Study were applied based on the American Community Survey from the US Census.

total recreational screen time and substance use in early adolescents.

These findings are consistent with prior literature detailing the positive association between screen use and substance use (Hull et al., 2014; Ko et al., 2008; Rücker et al., 2015). Social media specifically may influence substance use through pervasive and positive depictions of substance-related behaviors (Rutherford et al., 2023). Moreover, social media platforms are frequently utilized for marketing campaigns promoting alcohol, nicotine, and cannabis products (Berg et al., 2023; Lee et al., 2023; Room and O'Brien, 2021). This may be of particular concern as current literature suggests adolescents may be more susceptible to

substance-related content and advertising on social media due to limitations in impulse control and self-regulatory behaviors (Casey et al., 2008). Alternatively, consumption of social media may also result in mental health impacts, including desensitization and symptoms of anhedonia, which drive increasingly compulsive reward-seeking behaviors and coping mechanisms such as substance use (Christodoulou et al., 2020).

Our findings that text messaging and video calling are positively associated with substance use experimentation suggest that peer influence may also play an important role in influencing substance use experimentation. Substance use is commonly depicted by peers and influencers over media (Hendriks et al., 2023). Prior research has shown that substance-related media content from an individual's friends was associated with alcohol initiation in adolescents (Nesi et al., 2017). Additionally, adolescents overestimate their peers' engagement in these behaviors and subsequently conform to perceived norms of substance use (Watts et al., 2024). Furthermore, it is possible that peer interaction over these platforms, similar to peer interactions that occur in person, may actively increase pressure for social approval and influence risky behaviors such as substance use (Nesi and Prinstein, 2019; Schuler et al., 2019). This possibility is supported by neuroimaging studies that have demonstrated alterations in reward processing in the ventral striatum influenced by peer networks, which may lead to risky behaviors, including substance use (Chein et al., 2011; Crone and Konijn, 2018; Schreuders et al., 2018). In contrast, all other forms of screen use in our investigation, including TV, videos, video games, and the internet, do not require peer interaction and were not associated with any form of substance use experimentation. These results further suggest that peer influence may drive the relationship between screen time and substance use experimentation, which is in line with results from other studies within the broader adolescent population in the United States (Kaur et al., 2020). Future studies can consider further exploration of mediators influencing the association between social media, texting, and video calling and substance use experimentation, as well as potential interventions targeting identified mechanisms.

These findings have several public health and policy implications. Schools can consider implementing media literacy programs that teach students about the influence of digital content on behavior, including the normalization of substance use (Primack et al., 2014). Additionally, parents can consider monitoring and setting clear guidelines for adolescent screen use and holding discussions about the risks of screen use (Canadian Paediatric Society, Digital Health Task Force, Ottawa, Ontario, 2019). Parents should also monitor their own screen use behavior in order to model and promote healthy habits in adolescents (Nagata et al., 2024). Given that alcohol was consistently used initially as the substance selected by young adolescents, parents should also be educated about how its potential availability within the home environment may also facilitate early experimentation, even in early adolescents. Finally, warning labels informing parents, educators, and adolescents of the risks of screen use may be beneficial in reducing substance use associated with screen use (Abbasi and Hswen, 2024).

Our investigation has several limitations and strengths. First, the survey relies on self-reporting by respondents and is subject to recall bias. Despite this, most of the screen use modalities are used in a continuous, uninterrupted manner (e.g., watching television shows or movies, video chatting, playing video games, etc.), which have been shown to provide more accurate self-estimations compared to platforms that are used in a more fragmented and intermittent manner (Verbeij et al., 2021). Although the substance experimentation questions were adapted from the iSay Sip Inventory (Jackson et al., 2015), we are not aware of data reporting their psychometric validity. Given the sensitive nature of substance use in adolescence, it is possible that respondents underreported the outcome variable. There was a relatively low prevalence of cannabis experimentation (N=65) at Year 3 follow-up. Appendix A also shows that participants who were excluded were more likely to be from lower household income, lower parent education, and Latino, Black, Asian, or Other race and ethnicity. Given that those are groups that generally have higher screen time (Nagata et al., 2022) and possibly higher substance use (Simon et al., 2022; Small et al., 2014), this may bias results toward the null hypothesis. The final sampling outcome was not nationally representative, although the sample weighting with the American Community Survey attempted to improve the generalizability of study findings. Additionally, although we controlled for several potential confounders during our analysis (including demographic factors, socioeconomic factors, the family environment, the neighborhood environment, and baseline substance experimentation), it is possible that other confounding variables that were unaccounted for (including genetic and neurobiological factors) may be affecting the association between screen use and substance use and could be investigated in future research. Another limitation of the current study is that we were unable to identify mechanisms responsible for the observed associations between the three screen modalities and substance use experimentation. While the findings suggest that social connectivity may play a role, future longitudinal studies could utilize Social Influence Theory and Life Course Theory to investigate potential mediators in early adolescence, including peer norms, impulsivity, emotional regulation, and exposure to substance-related content (Kozak et al., 2019; Stellern et al., 2023; Trucco, 2020). Despite these limitations, our investigation has notable strengths. This study uses a large, diverse, national sample of early adolescents in the United States. Moreover, the prospective study design ensures that the exposure variable of screen use occurred prior to the outcome of substance use experimentation. Overall, we provide noteworthy evidence for an association between screen use and substance use in early adolescents.

## 5. Conclusion

This study highlights a significant association between screen use, namely social media, text messaging, and video calling, and substance use experimentation among early adolescents in the United States. While the findings are correlational, the prospective data increase confidence in our conclusions. Screen activities may contribute to increased alcohol, cannabis, and nicotine use through mechanisms such as peer influence and exposure to substance-related content. Given the pervasive nature of screen use among early adolescents, public health strategies should consider incorporating media literacy and warning labels that address the specific risks associated with different forms of screen use and their potential impact on substance use. Parents and schools can also implement interventions such as parental monitoring, including controlling the availability of substances within the home and education around healthy screen use habits to mitigate substance use associated with screen use.

## Funding

This research was supported by the National Institutes of Health, Bethesda, MD, USA (K08HL159350 and R01MH135492) and the Doris Duke Charitable Foundation, New York City, NY, USA (2022056). Recipient of all funding: Jason M. Nagata, MD, MSc.

## CRediT authorship contribution statement

**Alexander Testa:** Writing – review & editing. **Kyle T. Ganson:** Writing – review & editing. **Patrick Low:** Writing – review & editing, Writing – original draft. **Joan Shim:** Writing – review & editing, Writing – original draft, Formal analysis. **Fiona C. Baker:** Writing – review & editing, Methodology, Data curation. **Claire D. Brindis:** Writing – review & editing. **Glenn-Milo Santos:** Writing – review & editing. **Jinbo He:** Writing – review & editing. **Jason M. Nagata:** Writing – review & editing, Writing – original draft, Supervision, Formal analysis, Conceptualization. **Iris Y Shao:** Writing – review & editing, Formal analysis, Conceptualization.

## 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.

## Acknowledgements

The authors thank Anthony Kung for editorial assistance. The ABCD Study was supported by the National Institutes of Health and additional federal partners under award numbers U01DA041022, U01DA041025, U01DA041028, U01DA041048, U01DA041089, U01DA041093, U01DA041106, U01DA041117, U01DA041120, U01DA041134, U01DA041148, U01DA041156, U01DA041174, U24DA041123, and U24DA041147. A listing of participating sites and a complete listing of the study investigators can be found at https://abcdstudy.org/principal-investigators.html. ABCD consortium investigators designed and implemented the study and/or provided data but did not necessarily participate in the analysis or writing of this report. The opinions and assertions expressed herein are those of the author(s) and do not reflect the official policy or position of the Uniformed Services University of the Health Sciences or the Department of Defense.

## Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.drugalcdep.2024.112504.

## Data availability

Data used in the preparation of this article were obtained from the ABCD Study (https://abcdstudy.org), held in the NIMH Data Archive (NDA). Investigators can apply for data access through the NDA (https://nda.nih.gov/).

## References

Abbasi, J., Hswen, Y., 2024. US Surgeon General Vivek Murthy: to protect adolescents, social media needs warning labels. JAMA 332, 689–691. https://doi.org/10.1001/jama.2024.14245.

Acevedo-Garcia, D., Noelke, C., McArdle, N., Sofer, N., Hardy, E.F., Weiner, M., Baek, M., Huntington, N., Huber, R., Reece, J., 2020. Racial and ethnic inequities in children's neighborhoods: evidence from the New Child Opportunity Index 2.0. Health Aff. 39, 1693–1701. https://doi.org/10.1377/hlthaff.2020.00735.

Bagot, K.S., Tomko, R.L., Marshall, A.T., Hermann, J., Cummins, K., Ksinan, A., Kakalis, M., Breslin, F., Lisdahl, K.M., Mason, M., Redhead, J.N., Squeglia, L.M., Thompson, W.K., Wade, T., Tapert, S.F., Fuemmeler, B.F., Baker, F.C., 2022. Youth screen use in the ABCD® Study. Dev. Cogn. Neurosci. 57, 101150. https://doi.org/10.1016/j.dcn.2022.101150.

Barch, D.M., Albaugh, M.D., Baskin-Sommers, A., Bryant, B.E., Clark, D.B., Dick, A.S., Feczko, E., Foxe, J.J., Gee, D.G., Giedd, J., Glantz, M.D., Hudziak, J.J., Karcher, N.R., LeBlanc, K., Maddox, M., McGlade, E.C., Mulford, C., Nagel, B.J., Neigh, G., Palmer, C.E., Potter, A.S., Sher, K.J., Tapert, S.F., Thompson, W.K., Xie, L., 2021. Demographic and mental health assessments in the Adolescent Brain Cognitive Development Study: updates and age-related trajectories. Dev. Cogn. Neurosci. 52, 101031. https://doi.org/10.1016/j.dcn.2021.101031.

Benjamini, Y., Hochberg, Y., 1995. Controlling the false discovery rate: a practical and powerful approach to multiple testing. J. R. Stat. Soc.: Ser. B (Methodol. 57, 289–300. https://doi.org/10.1111/j.2517-6161.1995.tb02031.x.

Berg, C.J., LoParco, C.R., Cui, Y., Pannell, A., Kong, G., Griffith, L., Romm, K.F., Yang, Y. T., Wang, Y., Cavazos-Rehg, P.A., 2023. A review of social media platform policies that address cannabis promotion, marketing and sales. Subst. Abus. Treat. Prev. Policy 18, 35. https://doi.org/10.1186/s13011-023-00546-x.

Broyd, S.J., van Hell, H.H., Beale, C., Yücel, M., Solowij, N., 2016. Acute and chronic effects of cannabinoids on human cognition-a systematic review. Biol. Psychiatry 79, 557–567. https://doi.org/10.1016/j.biopsych.2015.12.002.

Canadian Paediatric Society, Digital Health Task Force, Ottawa, Ontario, 2019. Digital media: promoting healthy screen use in school-aged children and adolescents. Paediatr. Child Health 24, 402–417. https://doi.org/10.1093/pch/pxz095.

Casey, B.J., Jones, R.M., Hare, T.A., 2008. The adolescent brain. Ann. N. Y Acad. Sci. 1124, 111–126. https://doi.org/10.1196/annals.1440.010.

Chein, J., Albert, D., O'Brien, L., Uckert, K., Steinberg, L., 2011. Peers increase adolescent risk taking by enhancing activity in the brain's reward circuitry. Dev. Sci. 14, F1–F10. https://doi.org/10.1111/j.1467-7687.2010.01035.x.

Christodoulou, G., Majmundar, A., Chou, C.-P., Pentz, M.A., 2020. Anhedonia, screen time, and substance use in early adolescents: a longitudinal mediation analysis. J. Adolesc. 78, 24–32. https://doi.org/10.1016/j.adolescence.2019.11.007.

Cranwell, J., Whittamore, K., Britton, J., Leonardi-Bee, J., 2016. Alcohol and tobacco content in UK video games and their association with alcohol and tobacco use among young people. Cyber Behav. Soc. Netw. 19, 426–434. https://doi.org/10.1089/cyber.2016.0093.

Crone, E.A., Konijn, E.A., 2018. Media use and brain development during adolescence. Nat. Commun. 9, 588. https://doi.org/10.1038/s41467-018-03126-x.

Dick, A.S., Lopez, D.A., Watts, A.L., Heeringa, S., Reuter, C., Bartsch, H., Fan, C.C., Kennedy, D.N., Palmer, C., Marshall, A., Haist, F., Hawes, S., Nichols, T.E., Barch, D. M., Jernigan, T.L., Garavan, H., Grant, S., Pariyadath, V., Hoffman, E., Neale, M., Stuart, E.A., Paulus, M.P., Sher, K.J., Thompson, W.K., 2021. Meaningful associations in the Adolescent Brain Cognitive Development Study. Neuroimage 239, 118262. https://doi.org/10.1016/j.neuroimage.2021.118262.

Fandakova, Y., Hartley, C.A., 2020. Mechanisms of learning and plasticity in childhood and adolescence. Dev. Cogn. Neurosci. 42, 100764. https://doi.org/10.1016/j.dcn.2020.100764.

Garavan, H., Bartsch, H., Conway, K., Decastro, A., Goldstein, R.Z., Heeringa, S., Jernigan, T., Potter, A., Thompson, W., Zahs, D., 2018. Recruiting the ABCD sample: design considerations and procedures. Dev. Cogn. Neurosci., Adolesc. Brain Cogn. Dev. (ABCD) Consort.: Ration., Aims, Assess. Strategy 32, 16–22. https://doi.org/10.1016/j.dcn.2018.04.004.

Gil, A.G., Wagner, E.F., Tubman, J.G., 2004. Associations between early-adolescent substance use and subsequent young-adult substance use disorders and psychiatric disorders among a multiethnic male sample in South Florida. Am. J. Public Health 94, 1603–1609.

de Girolamo, G., Dagani, J., Purcell, R., Cocchi, A., McGorry, P.D., 2012. Age of onset of mental disorders and use of mental health services: needs, opportunities and obstacles. Epidemiol. Psychiatr. Sci. 21, 47–57. https://doi.org/10.1017/s2045796011000746.

Gonzalez, R., Thompson, E.L., Sanchez, M., Morris, A., Gonzalez, M.R., Feldstein Ewing, S.W., Mason, M.J., Arroyo, J., Howlett, K., Tapert, S.F., Zucker, R.A., 2021. An update on the assessment of culture and environment in the ABCD Study®: emerging literature and protocol updates over three measurement waves. Dev. Cogn. Neurosci. 52, 101021. https://doi.org/10.1016/j.dcn.2021.101021.

Guerrero, M.D., Barnes, J.D., Chaput, J.-P., Tremblay, M.S., 2019. Screen time and problem behaviors in children: exploring the mediating role of sleep duration. Int J. Behav. Nutr. Phys. Act. 16, 105. https://doi.org/10.1186/s12966-019-0862-x.

Hendriks, H., Thanh Le, T., Gebhardt, W.A., van den Putte, B., Vanherle, R., 2023. Dealing with alcohol-related posts on social media: using a mixed-method approach to understand young peoples' problem awareness and evaluations of intervention ideas. Int J. Environ. Res Public Health 20, 5820. https://doi.org/10.3390/ijerph20105820.

Hull, J.G., Brunelle, T.J., Prescott, A.T., Sargent, J.D., 2014. A longitudinal study of risk-glorifying video games and behavioral deviance. J. Pers. Soc. Psychol. 107, 300–325. https://doi.org/10.1037/a0036058.

Hutchison, E.D., 2017. Life course theory. In: Levesque, R.J.R. (Ed.), Encyclopedia of Adolescence. Springer International Publishing, Cham, pp. 1–10. https://doi.org/10.1007/978-3-319-32132-5_13-2.

Jackson, K.M., Barnett, N.P., Colby, S.M., Rogers, M.L., 2015. The prospective association between sipping alcohol by the sixth grade and later substance use. J. Stud. Alcohol Drugs 76, 212–221. https://doi.org/10.15288/jsad.2015.76.212.

Jackson, K.M., Janssen, T., Gabrielli, J., 2018. Media/marketing influences on adolescent and young adult substance abuse. Curr. Addict. Rep. 5, 146–157. https://doi.org/10.1007/s40429-018-0199-6.

Jordan, C.J., Andersen, S.L., 2017. Sensitive periods of substance abuse: early risk for the transition to dependence. Dev. Cogn. Neurosci. 25, 29–44. https://doi.org/10.1016/j.dcn.2016.10.004.

Kaur, N., Rutherford, C.G., Martins, S.S., Keyes, K.M., 2020. Associations between digital technology and substance use among U.S. adolescents: results from the 2018 Monitoring the Future survey. Drug Alcohol Depend. 213, 108124. https://doi.org/10.1016/j.drugalcdep.2020.108124.

Kelleghan, A.R., Leventhal, A.M., Cruz, T.B., Bello, M.S., Liu, F., Unger, J.B., Riehm, K., Cho, J., Kirkpatrick, M.G., McConnell, R.S., Barrington-Trimis, J.L., 2020. Digital media use and subsequent cannabis and tobacco product use initiation among adolescents. Drug Alcohol Depend. 212, 108017. https://doi.org/10.1016/j.drugalcdep.2020.108017.

Kelman, H., Tedeshi, J., 1974. Further thoughts on the processes of compliance, identification, and internalization. In: Perspectives on Social Power. Aldine, Chicago, pp. 125–171.

Ko, C.-H., Yen, J.-Y., Yen, C.-F., Chen, C.-S., Weng, C.-C., Chen, C.-C., 2008. The association between Internet addiction and problematic alcohol use in adolescents: the problem behavior model. Cyber Behav. 11, 571–576. https://doi.org/10.1089/cpb.2007.0199.

Kozak, K., Lucatch, A.M., Lowe, D.J.E., Balodis, I.M., MacKillop, J., George, T.P., 2019. The neurobiology of impulsivity and substance use disorders: implications for treatment. Ann. N. Y Acad. Sci. 1451, 71–91. https://doi.org/10.1111/nyas.13977.

Lee, J., Suttiratana, S.C., Sen, I., Kong, G., 2023. E-cigarette marketing on social media: a scoping review. Curr. Addict. Rep. 10, 29–37. https://doi.org/10.1007/s40429-022-00463-2.

Lisdahl, K.M., Sher, K.J., Conway, K.P., Gonzalez, R., Feldstein Ewing, S.W., Nixon, S.J., Tapert, S., Bartsch, H., Goldstein, R.Z., Heitzeg, M., 2018. Adolescent Brain Cognitive Development (ABCD) Study: overview of substance use assessment methods. Dev. Cogn. Neurosci. 32, 80–96. https://doi.org/10.1016/j.dcn.2018.02.007.

Moos, R.H., Moos, B.S., 1976. A typology of family social environments. Fam. Process 15, 357–371. https://doi.org/10.1111/j.1545-5300.1976.00357.x.
Moss, H.B., Chen, C.M., Yi, H.-Y., 2014. Early adolescent patterns of alcohol, cigarettes, and marijuana polysubstance use and young adult substance use outcomes in a nationally representative sample. Drug Alcohol Depend. 136, 51–62. https://doi.org/10.1016/j.drugalcdep.2013.12.011.
Nagata, J.M., Ganson, K.T., Iyer, P., Chu, J., Baker, F.C., Pettee Gabriel, K., Garber, A.K., Murray, S.B., Bibbins-Domingo, K., 2022. Sociodemographic correlates of contemporary screen time use among 9- and 10-year-old children, 213-220.e2 J. Pedia 240. https://doi.org/10.1016/j.jpeds.2021.08.077.
Nagata, J.M., Paul, A., Yen, F., Smith-Russack, Z., Shao, I.Y., Al-Shoaibi, A.A.A., Ganson, K.T., Testa, A., Kiss, O., He, J., Baker, F.C., 2024. Associations between media parenting practices and early adolescent screen use. Pedia Res. https://doi.org/10.1038/s41390-024-03243-y.
Nelson, S.E., Van Ryzin, M.J., Dishion, T.J., 2015. Alcohol, marijuana, and tobacco use trajectories from age 12 to 24 years: demographic correlates and young adult substance use problems. Dev. Psychopathol. 27, 253–277. https://doi.org/10.1017/S0954579414000650.
Nesi, J., Prinstein, M.J., 2019. In search of likes: longitudinal associations between adolescents' digital status seeking and health-risk behaviors. J. Clin. Child Adolesc. Psychol. 48, 740–748. https://doi.org/10.1080/15374416.2018.1437733.
Nesi, J., Rothenberg, W.A., Hussong, A.M., Jackson, K.M., 2017. Friends' alcohol-related social networking site activity predicts escalations in adolescent drinking: mediation by peer norms. J. Adolesc. Health 60, 641–647. https://doi.org/10.1016/j.jadohealth.2017.01.009.
Orben, A., Przybylski, A.K., Blakemore, S.-J., Kievit, R.A., 2022. Windows of developmental sensitivity to social media. Nat. Commun. 13, 1649. https://doi.org/10.1038/s41467-022-29296-3.
Primack, B.A., Douglas, E.L., Land, S.R., Miller, E., Fine, M.J., 2014. Comparison of media literacy and usual education to prevent tobacco use: a cluster-randomized trial. J. Sch. Health 84, 106–115. https://doi.org/10.1111/josh.12130.
Room, R., O'Brien, P., 2021. Alcohol marketing and social media: a challenge for public health control. Drug Alcohol Rev. 40, 420–422. https://doi.org/10.1111/dar.13160.
Rücker, J., Akre, C., Berchtold, A., Suris, J.-C., 2015. Problematic internet use is associated with substance use in young adolescents. Acta Paediatr. 104, 504–507. https://doi.org/10.1111/apa.12971.
Rutherford, B.N., Lim, C.C.W., Johnson, B., Cheng, B., Chung, J., Huang, S., Sun, T., Leung, J., Stjepanović, D., Chan, G.C.K., 2023. TurntTrending: a systematic review of substance use portrayals on social media platforms. Addiction 118, 206–217. https://doi.org/10.1111/add.16020.
Santos, R.M.S., Mendes, C.G., Sen Bressani, G.Y., de Alcantara Ventura, S., de Almeida Nogueira, Y.J., de Miranda, D.M., Romano-Silva, M.A., 2023. The associations between screen time and mental health in adolescents: a systematic review. BMC Psychol. 11, 127. https://doi.org/10.1186/s40359-023-01166-7.
Schreuders, E., Braams, B.R., Blankenstein, N.E., Peper, J.S., Güroğlu, B., Crone, E.A., 2018. Contributions of reward sensitivity to ventral striatum activity across adolescence and early adulthood. Child Dev. 89, 797–810. https://doi.org/10.1111/cdev.13056.
Schuler, M.S., Tucker, J.S., Pedersen, E.R., D'Amico, E.J., 2019. Relative influence of perceived peer and family substance use on adolescent alcohol, cigarette, and marijuana use across middle and high school. Addict. Behav. 88, 99–105. https://doi.org/10.1016/j.addbeh.2018.08.025.
Simon, K.M., Levy, S.J., Bukstein, O.G., 2022. Adolescent substance use disorders. NEJM Evid. 1, EVIDra2200051. https://doi.org/10.1056/EVIDra2200051.
Simons-Morton, B., 2007. Social influences on adolescent substance use. Am. J. Health Behav. 31, 672–684. https://doi.org/10.5555/ajhb.2007.31.6.672.
Small, E., Suzuki, R., Maleku, A., 2014. The impact of family and parental education on adolescents' substance use: a study of U.S. high school seniors. Soc. Work Public Health 29, 594–605. https://doi.org/10.1080/19371918.2014.893855.
Stellern, J., Xiao, K.B., Grennell, E., Sanches, M., Gowin, J.L., Sloan, M.E., 2023. Emotion regulation in substance use disorders: a systematic review and meta-analysis. Addiction 118, 30–47. https://doi.org/10.1111/add.16001.
Stiglic, N., Viner, R.M., 2019. Effects of screentime on the health and well-being of children and adolescents: a systematic review of reviews. BMJ Open 9, e023191. https://doi.org/10.1136/bmjopen-2018-023191.
Sullivan, R.M., Wade, N.E., Wallace, A.L., Tapert, S.F., Pelham, W.E., Brown, S.A., Cloak, C.C., Ewing, S.W.F., Madden, P.A.F., Martz, M.E., Ross, J.M., Kaiver, C.M., Wirtz, H.G., Heitzeg, M.M., Lisdahl, K.M., 2022. Substance use patterns in 9 to 13-year-olds: longitudinal findings from the Adolescent Brain Cognitive Development (ABCD) Study. Drug Alcohol Depend. Rep. 5, 100120. https://doi.org/10.1016/j.dadr.2022.100120.
Taber, K.S., 2018. The use of Cronbach's Alpha when developing and reporting research instruments in science education. Res Sci. Educ. 48, 1273–1296. https://doi.org/10.1007/s11165-016-9602-2.
Trucco, E.M., 2020. A review of psychosocial factors linked to adolescent substance use. Pharmacol. Biochem. Behav. 196, 172969. https://doi.org/10.1016/j.pbb.2020.172969.
Verbeij, T., Pouwels, J.L., Beyens, I., Valkenburg, P.M., 2021. The accuracy and validity of self-reported social media use measures among adolescents. Comput. Hum. Behav. Rep. 3, 100090. https://doi.org/10.1016/j.chbr.2021.100090.
Wade, N.E., Ortigara, J.M., Sullivan, R.M., Tomko, R.L., Breslin, F.J., Baker, F.C., Fuemmeler, B.F., Howlett, K.D., Lisdahl, K.M., Marshall, A.T., Mason, M.J., Neale, M.C., Squeglia, L.M., Wolff-Hughes, D.L., Tapert, S.F., Bagot, K.S., 2021. Passive sensing of preteens' smartphone use: an Adolescent Brain Cognitive Ddevelopment (ABCD) cohort substudy. JMIR Ment. Health 8, e29426. https://doi.org/10.2196/29426.
Watts, L.L., Hamza, E.A., Bedewy, D.A., Moustafa, A.A., 2024. A meta-analysis study on peer influence and adolescent substance use. Curr. Psychol. 43, 3866–3881. https://doi.org/10.1007/s12144-023-04944-z.
Welty, L.J., Hershfield, J.A., Abram, K.M., Han, H., Byck, G.R., Teplin, L.A., 2017. Trajectories of substance use disorder in youth after detention: a 12-year longitudinal study. J. Am. Acad. Child Adolesc. Psychiatry 56, 140–148. https://doi.org/10.1016/j.jaac.2016.10.018.
Zucker, R.A., Gonzalez, R., Feldstein Ewing, S.W., Paulus, M.P., Arroyo, J., Fuligni, A., Morris, A.S., Sanchez, M., Wills, T., 2018. Assessment of culture and environment in the adolescent rain Cognitive Development Study: rationale, description of measures, and early data. Dev. Cogn. Neurosci. 32, 107–120. https://doi.org/10.1016/j.dcn.2018.03.004.