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Substance use patterns in 9-10 year olds: Baseline findings from the adolescent brain cognitive development (ABCD) study

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ABSTRACT

Background: The Adolescent Brain Cognitive Development ™ Study (ABCD Study®) is an open-science, multi-site, prospective, longitudinal study following over 11,800 9- and 10-year-old youth into early adulthood. The ABCD Study aims to prospectively examine the impact of substance use (SU) on neurocognitive and health outcomes. Although SU initiation typically occurs during teen years, relatively little is known about patterns of SU in children younger than 12.

Methods: This study aims to report the detailed ABCD Study® SU patterns at baseline (n = 11,875) in order to inform the greater scientific community about cohort's early SU. Along with a detailed description of SU, we ran mixed effects regression models to examine the association between early caffeine and alcohol sipping with demographic factors, externalizing symptoms and parental history of alcohol and substance use disorders (AUD/SUD).

Primary Results: At baseline, the majority of youth had used caffeine (67.6 %) and 22.5 % reported sipping alcohol (22.5 %). There was little to no reported use of other drug categories (0.2 % full alcohol drink, 0.7 % used nicotine, <0.1 % used any other drug of abuse). Analyses revealed that total caffeine use and early alcohol sipping were associated with demographic variables (p's<.05), externalizing symptoms (caffeine p = 0002; sipping p = .0003), and parental history of AUD (sipping p = .03).

Conclusions: ABCD Study participants aged 9–10 years old reported caffeine use and alcohol sipping experimentation, but very rare other SU. Variables linked with early childhood alcohol sipping and caffeine use should be examined as contributing factors in future longitudinal analyses examining escalating trajectories of SU in the ABCD Study cohort.

1. Background

The Adolescent Brain Cognitive Development ™Study (ABCD Study®) is an epidemiologically informed prospective cohort study aimed at understanding the many factors that influence child and adolescent development (Volkow, Koob et al. 2018) (Jernigan, Brown et al. 2018). Over 11,800 youth aged 9–10 were recruited at baseline and are being followed for 10 years, in order to understand the developmental interaction between culture and environment (Zucker, Gonzalez et al. 2018), mental and physical health (Barch, Albaugh et al. 2018), substance use (SU) attitudes and exposure (Lisdahl, Sher et al. 2018), biological functioning (Uban, Horton et al. 2018), and genetics (Iacono, Heath et al. 2018) on neurocognitive development (Casey, Cannonier et al. 2018) (Luciana, Bjork et al. 2018).

The initiation of SU typically begins in adolescence, a period of ongoing neuromaturation (Casey, Giedd et al. 2000; Gardner and Steinberg, 2005; Eaton, Kann et al. 2006; Casey, Getz et al. 2008) (Giedd, Snell et al. 1996; Sowell, Thompson et al. 1999; Sowell, Trauner et al. 2002; Gogtay, Giedd et al. 2004; Sowell, Thompson et al. 2004; Lenroot and Giedd, 2006; Somerville, Jones et al. 2010; Houston, Herting et al. 2014; Mills, Goddings et al. 2014; Schmitt, Neale et al. 2014). In the United States, the national Monitoring the Future (MTF) Study identified an appreciable proportion of SU among eighth graders in 2019, including alcohol (24.5 %), cannabis (aka marijuana) (15.2 %), vaping including electronic nicotine delivery systems (ENDS, 20.3 %; 18.9 % JUUL), cigarettes (10.0 %), inhalants (9.5 %), smokeless tobacco (7.1 %), and misuse of prescription amphetamines (6.8 %), while a small percentage reported other illicit drug use (2.4 % hallucinogens, 1.7 % ecstasy, 1.2 % cocaine, 0.9 % methamphetamine, 0.7 % heroin) (Johnston et al., 2020). It is notable that published national data for SU among youth as young as 9 or 10 years old (the baseline age of the ABCD Study cohort) are uncommon, as the youngest age assessed in American national surveys is 12 years old [e.g., the National Survey on Drug Use and Health (Quality, 2014) begins at age 12, MTF Study starts at age 13 (Johnston et al., 2020)]. Data on school-aged children are primarily available at the state level (Donovan, 2007) (Donovan, 2013) for caffeine usage (Ahluwalia, Herrick et al. 2014; Ahluwalia and Herrick, 2015) or early alcohol sipping (Donovan, 2013) (Donovan and Molina, 2014) (Jackson et al., 2015a, 2015b). One of the larger state surveys available on 4th-6th graders is the Texas School Survey on Drug and Alcohol Use (Institute, 2012); this self-report survey found that 12.7 % of 4th graders had already used any alcohol, 11.1 % used inhalants, 2.8 % used nicotine products, and a small fraction used cannabis (0.8 %). Given the goals of prospectively studying the impact of SU on neurocognitive and health outcomes, it is important to fully characterize any SU reported by ABCD Study youth at baseline.

Few longitudinal or epidemiological studies focused on adolescent SU have assessed caffeine use and its influence on health outcomes, although addiction scientists have raised concerns over potential effects of caffeine use on decision-making and addiction risk (Budney and Emond, 2014) (Temple, Bernard et al. 2017) (Temple, 2009) (Curran and Marczinski, 2017). Caffeine use is common (73.9 %), even in elementary school-aged children (6−11-year olds) (Ahluwalia, Herrick et al. 2014; Ahluwalia and Herrick, 2015); accordingly, the ABCD Study SU Module integrated caffeine use measures in its protocol (Lisdahl, Sher et al. 2018). After caffeine, alcohol remains the most commonly used substance of abuse in adolescents (Miech et al., 2018). Initiation of alcohol often starts with sipping, defined as taking a sip of alcohol without consuming a full standard drink (Donovan, 2007) (Donovan and Molina, 2008). The typical age of alcohol sipping initiation is between 9 and 14 years old (Jackson et al., 2015a, 2015b) (Jackson, Ennett et al. 2013; Wadolowski et al., 2015a, 2015b) (Wadolowski et al., 2015a,

2015b). However, Donovan and colleagues observed that 35 % of 8-year-olds engaged in alcohol sipping in a sample of 452 children in Pennsylvania (Donovan and Molina, 2008). In a prospective web-based community study on alcohol initiation in 561 students, Jackson and colleagues (Jackson, Barnett et al. 2015) found that the prevalence of sipping alcohol by fall of sixth grade was 29.5 %. Of concern, sipping by sixth grade predicted greater odds of full alcohol drink consumption, getting "drunk," heavy drinking by ninth grade (Jackson, Barnett et al. 2015), and early adolescent drinking is associated with greater risk of developing an alcohol use disorder (AUD) (Grant and Dawson, 1997). Thus, carefully measuring early alcohol sipping patterns and understanding risk factors for sipping initiation may facilitate development of prevention campaigns to reduce risky adolescent drinking.

In sum, SU initiation can begin in early adolescence; however, few studies have reported SU patterns in a large cohort of elementary school-aged children. Further, no studies to date examined whether common factors linked with later SU (e.g., sex at birth, individual and household demographics, family history of substance use disorder (SUD), or youth externalizing symptoms) are associated with childhood caffeine and alcohol use patterns. Most notably, the ABCD Study was designed to assess the complex environmental, biological, psychiatric and health factors *prior to* the onset of regular substance exposure in order to characterize the timing and impact of escalating SU on neurocognitive and mental health outcomes (Lisdahl, Sher et al. 2018). Thus, the current study aims to provide a detailed description of the baseline SU patterns in youth enrolled in the ABCD Study. Further, we reported whether individual and household demographic variables (Garavan, Bartsch et al. 2018), parental history of AUD and SUD, and youth externalizing behaviors (variables utilized to recruit and stratify the sample based on SU risk (Loeber, Clark et al. 2018)) are associated with early caffeine and alcohol sipping use at baseline in youth enrolled in the study. This information can help guide the scientific community in considering factors that must be considered in relation to very early substance use experimentation in the ABCD Study cohort.

2. Methods

2.1. Participants and procedures

Participants in the current study included 11,857 youth who enrolled in the ABCD Study and completed the baseline session. The ABCD Study is a multi-site longitudinal study that enrolled 11,880 9- and 10-year-old racially/ethnically diverse youth (47.8 % female) at baseline at 21 U.S. research sites between 2016–2018, and is following the youth and parents/guardians annually for ten years into early adulthood (Jernigan, Brown et al. 2018; Volkow, Koob et al. 2018). Baseline recruitment used a stratified probability sample of eligible schools (selected for sex at birth, race/ethnicity, socioeconomic status, urbanicity) to match the demographic profile of the American Community Survey 3rd and 4th grade enrollment statistics within research catchment areas (for details, see (Garavan, Bartsch et al. 2018)). All study procedures were approved by the centralized institutional review board (IRB) at the University of California San Diego and by the local site IRBs. Potential participants were excluded for the following reasons: child not fluent in English, magnetic resonance imaging (MRI) contraindication, major neurological disorder, gestational age less than 28 weeks or birth weight less than 1,200 g, birth complications that resulted in hospitalization for more than one month, uncorrected vision, or current diagnosis of schizophrenia, autism spectrum disorder (moderate, severe), intellectual disability, or alcohol/substance use disorder (note: although this was exclusionary at baseline, no youth were excluded for SUD/DUD). Informed consent was obtained from parents/caregivers and assent from youth.

At baseline, youth and at least one parent or guardian participated in 1–2 in-person sessions, during which they completed a comprehensive battery of behavioral and biological assessment modules that were outlined in detail elsewhere: mental and physical health (Barch, Albaugh et al. 2018), SU (Lisdahl, Sher et al. 2018), peer, family, culture, and environment (Zucker, Gonzalez et al. 2018), biological functioning (Uban, Horton et al. 2018), genetics (Iacono, Heath et al. 2018), and neuropsychological and magnetic resonance imaging brain scans (Casey, Cannonier et al. 2018; Luciana, Bjork et al. 2018). For the vast majority of modules, all questionnaires were converted for electronic data capture via REDCap (Harris, Taylor et al. 2009) that were harmonized across sites (Auchter, Hernandez Mejia et al. 2018) (Casey, Cannonier et al. 2018) and administered on an iPad. Youth were interviewed separately from parents in a private space. The current study primarily utilized data from the SU, demographic, and mental health modules (see (Barch, Albaugh et al. 2018), (Lisdahl, Sher et al. 2018) for details).

During the SU module, rules regarding confidentiality and privacy were reiterated to the youth and they were asked if they had "heard of" a list of substances (including caffeine, alcohol, nicotine products, cannabis products, prescription or OTC drugs, inhalants, and "any other drug"'; for the latter, the youth listed off those drugs and the RA indicated their endorsement on a drop-down menu with all drug categories) (Lisdahl, Sher et al. 2018). The remainder of the interview utilized gating, in that youth were not asked direct questions about substances that they had *never heard of,* or follow-up questions about substances they had never used. If a youth had not "heard of" a drug category, then their reported use of the drug at that time-point was coded as zero.

2.2. Measures

2.2.1. Demographic factors

Identity and household demographic factors were included in the multivariable analyses as covariates; these included age at time of assessment, sex assigned at birth, race/ethnicity [NDA 2.01 release coded variable including primary ethnic/racial categories (non-Hispanic White, Hispanic, Black, Asian, Other/Multi-ethnic)], highest parental/guardian education, parental/guardian marital status, and parental/guardian combined household income (see (Barch, Albaugh et al. 2018)).

2.2.2. Alcohol, tobacco, and Cannabis low-level/first use

If youth heard of alcohol, they completed the iSay Sipping Inventory (Jackson, Barnett et al. 2015; Jackson, Colby et al. 2015), an 8-item measure of recent alcohol sipping that also characterized their first alcohol sipping experience. Participants reported whether they ever had a sip of alcohol, number of times had a sip of alcohol in lifetime, whether they sipped alcohol outside of a religious occasion (yes/no), total times had a sip of alcohol (outside of a religious setting), the age of first sip (outside of a religious context), whether they finished their first alcoholic drink, what type of alcohol was tried the first time they sipped, to whom the drink belonged, whether the sip was offered or taken without permission, and whether the youth remembered trying the alcohol or if she/he was told about it later. First use of nicotine or cannabis products was also assessed, including number of times used, age of first use, where/from whom they obtained the substance, and whether it led to further use (Lisdahl, Sher et al. 2018). For cannabis, whether they remembered or were told about their first use and subjective experience of feeling "high" during the first use were also measured.

2.2.3. Lifetime & past 6-Month SU patterns

Youth were asked if they used each major drug category ever in their lifetime; multiple formal and informal names (including popular "street" names) of each substance were used (e.g., "alcohol such as beer, wine, or liquor – such as rum, vodka, gin, whiskey" for further details for each drug category see: (Lisdahl, Sher et al. 2018)). If a youth endorsed using the substance in the past six months, a detailed web-based Timeline Follow-Back (TLFB) interview (Sobell and Sobell, 1996) (Robinson, Sobell et al. 2014) was administered (for details see (Lisdahl, Sher et al. 2018)). The TLFB uses a calendar-based interviewer-administered

retrospective report of detailed quantity/frequency SU patterns during the past 6 months at baseline; for follow-up years, the entire period between sessions is assessed. Substances assessed for the lifetime SU and TLFB interviews included alcohol, nicotine products (cigarettes, electronic nicotine delivery systems (ENDS)[1], smokeless tobacco, cigars, hookah, pipe, and nicotine replacement products), cannabis products (smoked/vaped flower, smoked blunts, edibles, smoked/vaped concentrates, oral tinctures, and cannabis-infused alcohol drinks, synthetic cannabinoids), cocaine, cathinones, methamphetamine, ecstasy/MDMA, ketamine, gamma-hydroxybutyrate (GHB), heroin, psilocybin, salvia, other hallucinogens (LSD, PCP, synthetic hallucinogens), anabolic steroids, inhalants, prescription stimulants, sedatives, and opioid pain relievers, and over the counter (OTC) cough/cold medicine (Lisdahl, Sher et al. 2018).

2.2.4. Caffeine use

The average weekly number of total standard doses of caffeine beverages (8 oz cup for coffee or tea, espresso shot, 12 oz soda, or 8 oz energy drink) consumed over the past six months were measured at baseline (see (Lisdahl, Sher et al. 2018)).

2.2.5. Externalizing scale

Parents rated their child's externalizing (Rule-breaking Behavior, Aggressive Behavior) behaviors on the Child Behavior Checklist (CBCL; (TM, A., 2009)).

2.2.6. Parental history of alcohol and drug use disorder

We calculated a dummy-coded variable representing biological parental history of AUD and other drug use disorder (DUD) (no history/at least one parent with history/two parents having history) taken from the Family History Assessment Module Screener, which was filled out by the youth's participating parent or guardian (FHAM-S; (Rice, Reich et al. 1995)).

2.3. Statistical analysis

Analyses were conducted in R (v3.6.1) utilizing published ABCD Data Release 2.01 (https://data-archive.nimh.nih.gov/abcd; DOI: 10.15154/1504041, July 2019). First, we computed descriptive statistics for variables (data were examined for non-normality and outliers prior to analysis; no trimming or corrections were applied). Next, considering the cohort was balanced for sex and sex differences have been repeatedly reported in SU patterns, especially in adolescents (Johnston et al., 2020) (Windle, 2020) (Wilkinson, Halpern et al. 2016), we examined sex differences [chi-square (Yate's correction was employed if a cell was small) or *t*-test analyses] for all analyses.[2] Finally, in order to describe baseline relationships between demographic factors, externalizing behaviors, and parental history of AUD/SUD (Loeber, Clark et al. 2018), we ran Generalized Linear Mixed Effect (LME) (Laird and Ware, 1982) models for multivariable regression analyses utilizing the appropriate distribution of the outcome (i.e., Gaussian for continuous data, and Poisson for skewed count data) examining whether age at baseline, sex at birth, race/ethnicity, highest parental education, marital status, combined parental household income, CBCL externalizing T-score, and parental history of AUD and DUD were associated with total caffeine dose and alcohol sipping (total times had alcohol sips, total times had alcohol sips in non-religious context) outcomes after accounting for covariates (random effects for site and family ID (e.g., twin/triplet/sibling status)). Results were considered significant if they were at the $p < .05$ level; appropriate effect sizes (Cramer's V (denoted as φ_c), Cohen's d, and beta weights) were included for interpretation.

3. Results

3.1. Demographic variables

Of the total baseline sample, 11,857 (99.8 %) completed the SU assessment module. For overall sample demographics of the baseline ABCD participants, see Table 1.

3.2. "Heard of" results

3.2.1. "Heard of" descriptives

The majority of youth in the sample endorsed having heard of alcohol (96.3 %), caffeine (94.3 %), nicotine products (93.4 %), and cannabis products (55.6 %), while fewer youth had heard of prescription or OTC drug misuse (34.8 %) or inhalants (25.6 %) (see Table 2). Only a small minority of youth had heard of "any other drug": cocaine (5.4 %), heroin (1.7 %), methamphetamine (1.3 %), anabolic steroids (0.9 %), salvia (<0.1 %), psilocybin (0.2 %), other hallucinogens (0.3 %), cathinones (<0.1 %), MDMA (<0.1 %), GHB (<0.1 %), and ketamine (<0.1 %).

3.2.2. Sex differences: "heard of" items

Males were significantly more likely than females to report having heard of nicotine ($\chi^2(1) = 6.1$, $p = 0.013$, $\varphi_c = 0.02$), cannabis ($\chi^2(1) = 91.9$, $p = 2.2e\text{-}16$, $\varphi_c = 0.09$), and inhalants ($\chi^2(1) = 36.5$, $p = 1.208e\text{-}08$, $\varphi_c = 0.05$), no differences were seen in hearing of alcohol, caffeine, prescription/OTC drugs, or inhalants; see Table 2.

3.3. Substance use patterns

3.3.1. Caffeine use

The majority (67.6 %) of youth reported consuming at least one type of caffeinated beverage during the past six months and the most popular beverage was soda (57.8 %; see Table 2). A small minority of youth (7.4 %) reported ingesting at least one standard dose of caffeine per week on average; see Table 3 & Fig. 1 for details by beverage type.

3.3.2. Alcohol use

The next most commonly used substance was alcohol, with 22.5 % (n = 2673) of youth reporting having a sip of alcohol in their lifetime. In contrast, only 21 youth reported having using a full drink of alcohol (0.18 %). Of those 22.5 % who reported sipping alcohol, youth reported sipping alcohol an average of 4.7 total times in their lifetime.[3] 17.1 % of the total sample reported non-religious alcohol sipping[4]; the median age of first non-religious sipping was 8 years old. Although several of the non-religious sippers (45.5 %) reported taking more than one sip, most youth did not finish the drink after consuming their first alcohol sip (98.4 %). The vast majority of youth remembered taking their first sip of alcohol versus being told about the event (93.2 %). See Table 4 for additional details.

3.3.3. Nicotine use

The next most commonly tried substance at baseline were nicotine products, as 81 (0.68 %) youth reported having a "puff" or taste of a tobacco product or ENDS in their lifetime. Of the 81 youth who reported any nicotine use, 75 (0.6 % of study participants) reported trying a puff of a tobacco product outside of a religious context. Twelve (0.1 %) youth

[1] At baseline, ENDS use is described as including "electronic cigarettes, vape pens, or e-hookah" and may include products that contain only flavoring. Whether the ENDS contains nicotine is asked as a follow-up question.

[2] If cells were small, then percentages are denoted <0.1 %.

[3] The iSay Sip inventory was missing for 4 participants who initially endorsed lifetime sipping.

[4] Due to an initial gating error in RedCap, follow-up questions in the iSay Sip inventory were only collected on 2,016 of the 2,034 youth who reported non-religious sipping.

Table 1
Demographic Characteristics, CBCL Externalizing Symptoms T-Score, and Parental Family History of AUD and DUD in Baseline ABCD Study Participants (who completed the SU Module).

	ABCD Participants (n = 11,857) Mean (SD) or %; Range
Age	9.9 (0.6); 9.0–10.9
Female	47.8 % (n = 5678)
Twin/Singleton Status	
Singleton	68.6 %
Siblings	13.4 %
Twin	17.7 %
Triplet	0.3 %
Race/Ethnicity	
Caucasian	52.0 %
Black	15.0 %
Asian-American	2.1 %
Hispanic	20.3 %
Others and >1 category)	10.1 %
Unknown	0.5 %
Parental Household Income	
<50,000	27.1 %
50,000–100,000	25.9%
>100,000	38.4%
Unknown	8.6 %
Parental Highest Education	
Post Graduate Degree	34.0 %
Bachelor's Degree	25.4 %
Some College	26.0 %
High School Diploma/GED	9.5 %
<High School Diploma	5.0 %
Unknown	0.1 %
Parental Marital Status % Married Families	67.3 %
CBCL Externalizing T-Score	45.7 (10.3); 33–84
Parental History of AUD	
No Parents	85.4 %
1 Parent	12.7 %
2 Parents	1.9 %
Parental History of SUD	
No Parents	89.3 %
1 Parent	8.6 %
2 Parents	2.1 %

Notes: Parent demographic variables include either parent or guardian/primary caregiver. CBCL = Child Behavior Checklist. Parental history of alcohol use disorder (AUD) and substance use disorder (SUD) was dummy-coded as density of biological parents meeting criteria for at least one symptom of AUD or SUD (0 = no parents met criteria, 1 = one parent met criteria, 2 = both parents met criteria) based on the FHAM-S.

Table 2
Substance Use Patterns in Baseline ABCD Study Participants According to Full Sample and Sex at Birth (n = 11,857).

Mean (SD) or %; Range	All (n = 11,857)	Boys (n = 6179)	Girls (n = 5678)
Heard of = YES…			
Caffeine	94.3 %	94.4 %	94.2 %
Alcohol	96.3 %	96.2 %	96.4 %
Nicotine Products*	93.4 %	93.9 %	92.8 %
Cannabis Products*	55.6 %	59.8 %	51.1 %
Inhalants*	25.6 %	27.9 %	23.1 %
Prescription Drug Abuse	34.8 %	34.9 %	34.6 %
Used Caffeine*	67.6 %	70.2 %	64.7 %
Sipped Alcohol*	22.5 %	24.3 %	20.6 %
Used Alcohol (full beverage)*	0.18 %	0.26 %	<0.1 %
Tried Any Nicotine Product*	0.68 %	0.89 %	0.37 %
Used Cigarette	<0.1 %	0.10 %	<0.1 %
Used ENDS	<0.1 %	0.13 %	<0.1 %
Used Cigar	<0.1 %	<0.1%	<0.1 %
Used Hookah	<0.1 %	<0.1 %	<0.1 %
Used Tobacco Pipe	<0.1 %	<0.1 %	<0.1 %
Used Nicotine Replacement	<0.1 %	<0.1 %	<0.1 %
Used Smokeless Tobacco	0.1 %	0.16 %	<0.1 %
Tried Any Cannabis Product*	0.1 %	0.18 %	<0.1 %
Smoked/Vaped Flower	<0.1 %	<0.1 %	0%
Smoked Blunt	<0.1 %	<0.1 %	0%
Used Edible	<0.1 %	<0.1 %	0%
Smoked/Vaped Concentrate	<0.1 %	<0.1 %	0%
Used Cannabis Tincture	<0.1 %	<0.1 %	0 %
Used Cannabis/Alcohol Drink	<0.1 %	<0.1 %	0 %
Used Synthetic THC	0 %	0 %	0 %
Used Other Illicit Drug…			
Inhalants	<0.1 %	<0.1 %	0 %
Rx Stimulants	<0.1 %	0 %	<0.1 %
Rx Opioids	<0.1 %	<0.1 %	0 %
Rx Sedatives	<0.1 %	<0.1 %	0 %
OTC Cough Medicine	0<0.1 %	<0.1 %	<0.1 %
Cocaine	0 %	0 %	0 %
Cathinone	<0.1 %	<0.1 %	0 %
Methamphetamine	0 %	0 %	0 %
Ecstasy/MDMA	0 %	0 %	0 %
Ketamine	0 %	0 %	0 %
GHB	0 %	0 %	0 %
Heroin/Opium	0 %	0 %	0 %
Hallucinogens	0 %	0 %	0 %
Psilocybin	0 %	0 %	0 %
Salvia	0 %	0 %	0 %
Anabolic Steroids	0 %	0 %	0 %

Notes: * = chi-square or *t*-test analyses revealed significant difference by sex.

reported trying smokeless tobacco. (See Table 4 for more details characterizing their first nicotine use, including type of product, age of first use, and use of flavoring.) Few (<0.1 %) youth reported having more than just a puff of a tobacco cigarette, further, few used ENDS (more than a puff) (<0.1 %), cigars (<0.1 %), smoked hookah tobacco (<0.1 %), smoked tobacco in a pipe (<0.1 %), or used a nicotine replacement product (<0.1 %). Few youth (0.1 %) in the sample used smokeless tobacco. See Table 2 and Fig. 2 for details.

3.3.4. Cannabis use

Twelve youth reported trying a "puff" or taste of a cannabis product (0.1 %). On average, at baseline those youth had 7.4 puffs or tastes (median = 1.5). For their first cannabis use, the majority smoked or vaped cannabis flower (75 %). On average, during their first use, they reported that they felt "buzzed" (M = 2.5, range 0–10 on a scale of 1–10). The vast majority (92 %) remembered their first time using (versus being told about it). (See Table 4 for more details regarding the youth's first cannabis use.) Only a few youth reported smoking or vaping *more than a puff* of cannabis flower (<0.1 % reported using any other modality including smoking a blunt, consuming a cannabis edible product, cannabis concentrate (e.g., vape pen, dabs), cannabis tincture, cannabis alcohol drink, and or using synthetic THC (see Table 2 and Fig. 2 for cannabis use details).

3.3.5. Other illicit SU

A very small subset (<0.1 % for each drug category) of youth reported use of any other illicit drugs (see Table 2 for use according to the whole cohort and by sex).

3.3.6. Sex differences in SU patterns[5]

Males were significantly more likely than females to report using

[5] [4]n=3 participants with substance use data had sex missing or reported response other than male or female for sex; due to low sample size they were excluded from this analysis.

Table 3
Caffeine Use Patterns in Baseline ABCD Study Participants.

	Caffeine Users (n = 8018) [% or Mean (SD)]
% Used Caffeine Beverage	67.6 %
Soda	57.8 %
Tea	28.9 %
Coffee	14.7 %
Espresso	7.7 %
Energy Drink	2.3 %
Average Standard Dose* Per Week	1.95
Soda	1.18 (4.56)
Tea	0.56 (2.81)
Coffee	0.15 (1.56)
Espresso	0.04 (0.38)
Energy Drink	0.02 (0.36)
% Used Caffeine Daily	7.4 %
Soda	4.2 %
Tea	2.4 %
Coffee	0.4 %
Espresso	<0.1 %
Energy Drink	<0.1 %

* Dose = 1 8 oz cup for coffee or tea, 1 shot espresso, 12 oz soda, or 8 oz energy drink.

caffeine ($\chi^2(1) = 40.8$, $p = 1.7e\text{-}10$, $\varphi_c = 0.06$), sipping alcohol ($\chi^2(1) = 22.8$, $p = 0.000002$, $\varphi_c = 0.04$), having a full alcohol drink ($\chi^2(1) = 3.96$, $p = 0.05$, $\varphi_c = 0.02$), puffing/trying a tobacco product ($\chi^2(1) = 7.5$, $p = 0.006$, $\varphi_c = 0.03$), and puffing or trying a cannabis product ($\chi^2(1) = 6.02$, $p = 0.01$, $\varphi_c = 0.03$). Males also reported significantly greater caffeine total dose (t(11,264)=-2.6, $p = 0.02$, d=0.04) and greater total non-religious alcohol sips (t(11,747)=-2.47, $p = 0.01$, d=0.05). There were no sex differences for any of the other SU outcomes (notably, there was *very little use* reported for other substances); see Table 2 for use rates according to sex at birth.

3.4. Multivariable predictors of caffeine & alcohol

3.4.1. Total caffeine use

After statistically controlling for other demographics variables (sex, parental marital status, household income, parental history of AUD/DUD) and accounting for site and twin/sibling status, we found that 10-year-olds (vs. 9-year-olds; $b = .02$, $t = 2.2$, $p = 0.03$), Hispanic youth (vs. Caucasian; b=-.40, t=-2.1, $p = 0.03$), youth from families with lower parental education (less than high school (HS) diploma vs. Bachelor degree, b=-1.2, $t = 3.4$, $p = 0.0007$; less than HS diploma vs. post-graduate degree, b=-1.53, t=-4.3, $p = 0.00002$), and youth with greater CBCL externalizing behaviors ($b = .02$, t = 3.7, p = 0.0002) reported significantly greater total average caffeine dosage per week (*see* Fig. 3).

3.4.2. Total times had sip of alcohol

After controlling for the other demographic variables, site and twin/sibling status, 10-year-olds (vs. 9-year-olds; $b = .02$, $t = 6.1$, $p = 1.4e\text{-}09$), Caucasian youth (vs. African-American youth; b=-.21, t=-2.0, $p = 0.05$), youth from married households (vs. unmarried households; $b = .16$, $t = 2.3$, $p = 0.02$), and youth with greater CBCL externalizing behaviors ($b = .008$, $t = 3.7$, $p = 0.0003$) reported greater total number times they had a sip of alcohol.

3.4.3. Total times had sip alcohol (Non-Religious context)

We also found that 10-year-olds (vs. 9-year-olds; b=-.01, $t = 9.0$, $p = 2e\text{-}16$), boys (vs. girls; b=-.15, t=-3.1; $p = 0.002$), Caucasian youth (vs. Asian-American youth; b=-.40, t=-2.0, $p = 0.05$), and youth with a negative history of parental AUD (vs. positive parental history; b=-.15, t=-2.1, $p = 0.03$) reported greater total number of times they had a sip of alcohol (non-religious context) (*see* Fig. 4).

4. Discussion

The ABCD Study is the largest prospective study to date to examine the impact of various SU patterns on neurocognitive, health and affective outcomes. The sample is particularly unique in that it is large, geographically and demographically diverse, and provides detailed yearly assessments of individual/biological, neurocognitive, peer, family, cultural, and environment factors that can be harnessed to prospectively examine the onset, trajectories, and sequala of SU in adolescents (Jernigan, Brown et al. 2018; Volkow, Koob et al. 2018). Before scientists begin to examine predictors of SU initiation and trajectories in longitudinal analyses, full characterizing of the baseline SU patterns is needed. Here, we found that the most common early SU behavior was consuming caffeinated beverages (67.6 %). Second to that was sipping alcohol (22.5 %). Most notably, aside from caffeine use and sipping alcohol, SU was very low at baseline (0.7 % for trying a nicotine product, 0.1 % trying a cannabis product, and <0.1 % for trying any other drug of abuse). Although very minimal SU initiation was reported, boys demonstrated an overall pattern of greater early use compared to girls. Further, demographics including age, ethnicity/race, parental education, marital status, parental history of AUD and youth externalizing behaviors were linked with early caffeine or alcohol sipping behavior, although effect sizes were generally small.

Given the common use of caffeinated beverages in children and teens (Ahluwalia and Herrick, 2015), and the growing concerns over health effects and addiction risk associated with excessive caffeine use (Budney and Emond, 2014) (Temple, Bernard et al. 2017) (Temple, 2009), examining caffeine effects on health and neurodevelopment in youth is of increasing importance. The majority of the 9- and 10-year-olds in the ABCD cohort already initiated some low-level caffeine use at baseline,

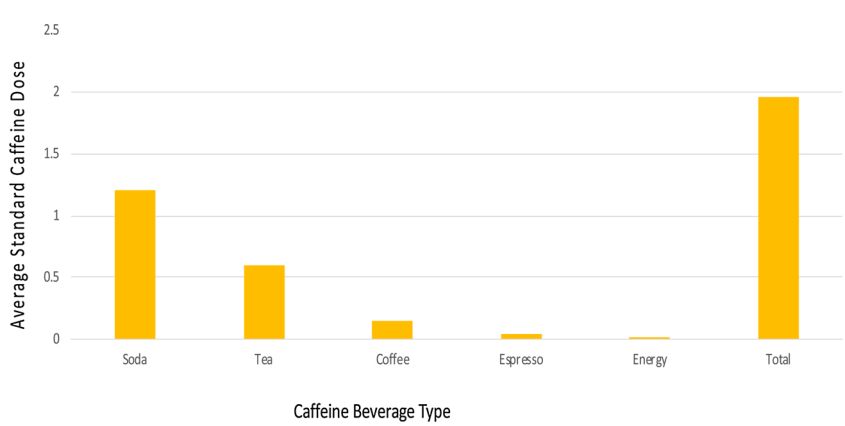

Fig. 1. Average Caffeine Standard Dose per Week (Past 6 Months) for Soda, Tea, Coffee, Espresso, Energy Drinks, and Total Combined Dose in Baseline ABCD Study Participants. Dose = 8 oz cup for coffee or tea (532 mL), 1 shot espresso (30 mL), 12 oz soda (355 mL), or 8 oz (236 mL) energy drink.

Table 4
Low-Level/First-Use Alcohol, Nicotine and Cannabis Use Patterns in Baseline ABCD Study Participants.

	Mean (SD) or %; Range
Sipped Alcohol (non-religious; full sample)	17.1 %
Total Sipping Occasions (full sample)	4.7 (19.2); 0–520
Total Sipping Occasions (non-religious)±	2.8 (7.67); 0–198
> 1 Sip (non-religious) ±	45.5 %
Did Not Complete First Drink±	98.4 %
Age of First Sip Onset (years) ±	7.32 (1.9); 1–11
Type of First Alcohol Sipped:±	
Beer	41.3 %
Wine/Champagne	30.3 %
Wine Cooler/Beer Substitute	5.1 %
Liquor Mixed Drink	3.9 %
Shots Liquor	2.3 %
Liqueur/Cordial	0.6 %
Malt Liquor	0.2 %
Fortified Wine	<0.1 %
Other	0.8 %
Don't Know	15.4 %
First Sipped Alcohol Belonged To:±	
Dad	42.1 %
Mom	37.0 %
Other Guardian	2.2 %
Other Adult Family Member	5.7 %
Aunt or Uncle	3.9 %
Another Adult (Non-Family)	2.2 %
Underage (<21 yrs old) Sibling	2.9 %
Sibling 21 or Older	2.9 %
Friend	0.2 %
Person <20 yrs old (Non-Friend)	0.2 %
Stranger	0.2 %
Don't Know	5.2 %
How Received First Alcohol: ±	
Offered Sip	72.8 %
Accidently Took Sip	21.9 %
Intentionally Took Sip	1.2 %
First Used Nicotine Product (n = 75) Type:	
Cigarette	38.7 %
ENDS	57.3 %
Cigar	4.3 %
Hookah	4.3 %
Tobacco Pipe	4.3 %
Nicotine Replacement	0 %
Age of First Nicotine Puff (years)	7.5 (1.9); 3–10
Did Not Continue After First Puff	85 %
Nicotine Product Flavoring:	
Menthol or Mint	10.7 %
Other Flavoring	36.0 %
No Flavoring	53.3 %
Tried Smokeless Tobacco (n = 12)	0.1 %
Age of First Use (years)	6.9 (1.7); 4–10
Did Not Continue After First Try	100 %
First Smokeless Tobacco Contained Flavoring:	
Menthol or Mint	16.7 %
Other Flavoring	8.3 %
No Flavoring	75 %
First Used Cannabis Product (n = 12) Type:	0.1 %
Smoked/Vaped Flower	75 %
Smoked/Vaped Strong/Potent Flower	8.3 %
Edible	8.3 %
Smoked/Vaped Concentrate or Oil	8.3 %
Tincture	0 %
Infused Alcohol Drink	0 %
Synthetic THC	0 %
Total Cannabis Puffs/Tastes	7.4 (12.3); 1–40
Age of First Cannabis Use (years) ±	8.5 (1.7); 4–10
Did Not Continue After First Try	83 %
First Cannabis Product Provided By:	
Dad	8.3 %
Mom	25.0 %
Other Guardian	0 %
Other Adult Family Member	8.3 %
Aunt or Uncle	16.7 %
Another Adult (Non-Family)	8.3 %
Younger (<21 yrs old) Sibling	16.7 %
Sibling 21yrs or Older	0 %
Friend	8.3 %
Person <20 yrs old (Non-Friend)	0 %
Stranger	0 %
Don't Know	8.3 %
How Received First Cannabis Product:	
Offered	50.0 %
Accidently Took	16.7 %
Intentionally Took	33.3 %

Notes: ± Alcohol data only includes youth who endorsed non-religious alcohol sipping (n = 2034). Low-level (aka, first use) nicotine and cannabis data only include youth who endorsed trying a nicotine (n = 75; n = 12) or cannabis product (n = 12).

although they on average only consumed around two standard doses of caffeine per week (most commonly soda). Still, a notable 7.4 % reported daily caffeine usage and a small group of youth (2.3 %) reported consumption of energy drinks- which can contain higher doses of caffeine. Older youth, youth from families with lower parental education, Hispanic youth (vs. Caucasian), and youth with higher externalizing scores reported greater weekly caffeine use; the effect sizes for all relationships were small, with the exception of parental education, which demonstrated a large effect at baseline. These factors will need to be examined longitudinally in the ABCD cohort to determine whether they represent long-term risk factors for problematic caffeine consumption (>400 mg per day), development of a caffeine use disorder (Evatt, Juliano et al. 2016), and to examine the links between caffeine use and health and neurocognitive outcomes during adolescence.

The second most commonly used substance was alcohol, with 22.5 % of youth reporting sipping alcohol (17.1 % outside of a religious context). In the users, the average number of times they sipped alcohol (non-religious) was relatively low (2.8 times) and the vast majority of the youth (98.4 %) did not continue to finish a full alcoholic drink after their first sip. Interestingly, for their first sip, the majority were offered the alcoholic beverage (72.8 %) by a parent or guardian (81.3 %). Risk-factors related to increased total times youth sipped alcohol included being older (10- vs. 9-years-old), Caucasian (vs. African-American), living in a married household (vs. unmarried household), and having greater CBCL externalizing behaviors. Further, older youth, boys (vs. girls), Caucasian youth (compared to Asian youth), and youth without a history of parental AUD also reported greater total times sipped alcohol outside of a religious context. Notably, all statistical effect sizes were considered to be in the small range, demonstrating subtle relationships at baseline. These findings are consistent with prior research demonstrating that sipping at this age (prior to high-school) generally occurs within a family context (Donovan and Molina, 2008) and alcohol beverages are being offered primarily by parents (Jackson, Barnett et al. 2015). Our findings are also consistent with prior smaller regional studies reporting increased risk of early sipping linked with increased age (Donovan, 2007), being Caucasian (vs. African-American) (Donovan and Molina, 2008) and male (Donovan, 2007). Uniquely, we found that youth from married households reported greater sipping occasions compared to unmarried households, which is partially discrepant with one prior study that reported an earlier age of onset of sipping in single-mother headed households (Donovan and Molina, 2011); however, it is notable that this effect size was small and our study did not specifically categorize whether the household was considered a single-mother headed household. Positive parental history of AUD was linked with fewer sipping occasions, a finding partially discrepant with regional studies finding parental drinking history to be positively

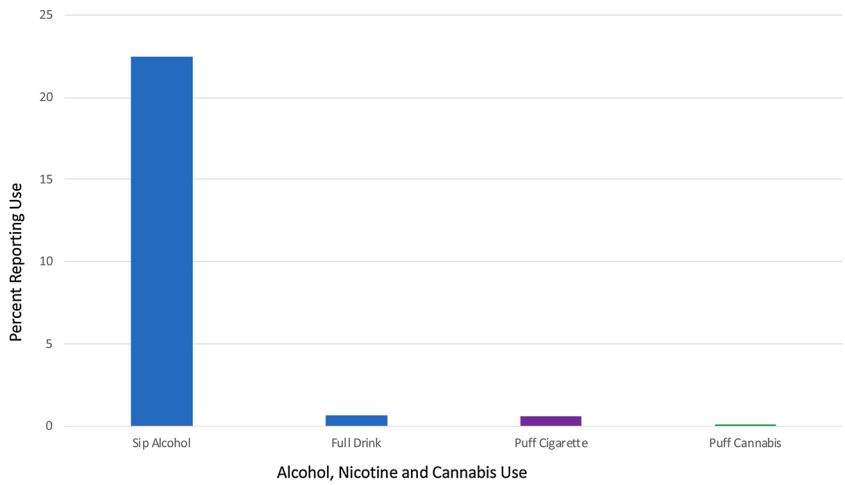

Fig. 2. Percentage of ABCD Participants Reporting Alcohol (Sip, Full Alcohol Drink), Nicotine (Puff/Taste), and Cannabis (Puff/Taste) Use at Baseline.

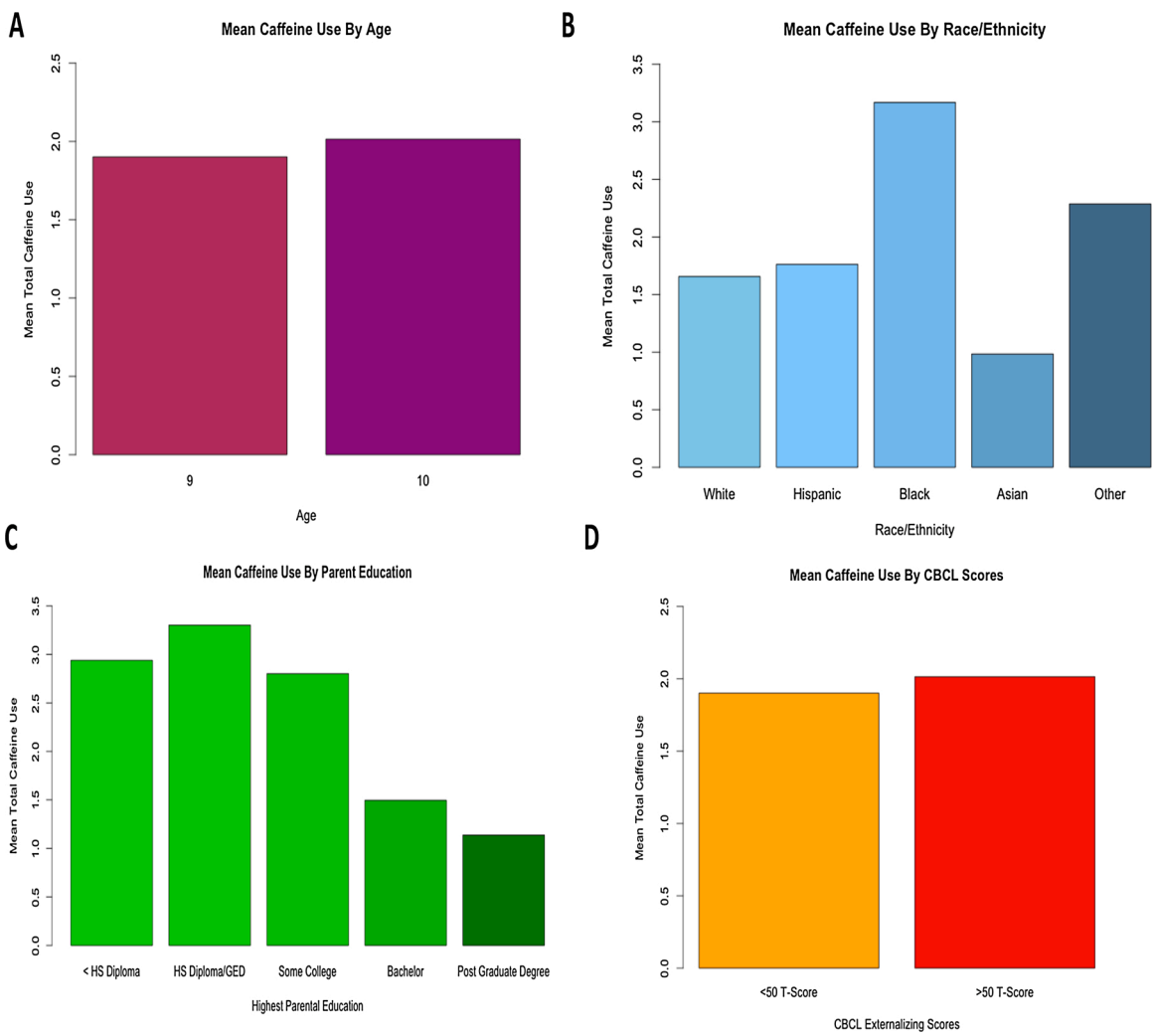

Fig. 3. Mean Caffeine Dose Per Week (Past Six Months) in Baseline ABCD Study Participants According to (A) Age, (B) Race/Ethnicity, (C) Highest Parental Education, and (D) CBCL Externalizing Behavior Scores.

associated with early adolescent sipping (Donovan and Molina, 2008) (Donovan and Molina, 2011). Examining the influence of parental AUD history on other influential factors such as parental monitoring, household alcohol rules, availability, alcohol expectancies and alcohol trajectories in the ABCD Study cohort will be an important future direction (Lisdahl et al., 2018). Consistent with the prior literature linking externalizing behaviors with development of SUD (e.g., (Grant and Dawson, 1997) (Dawson, Goldstein et al. 2008) (Loeber, Clark et al.

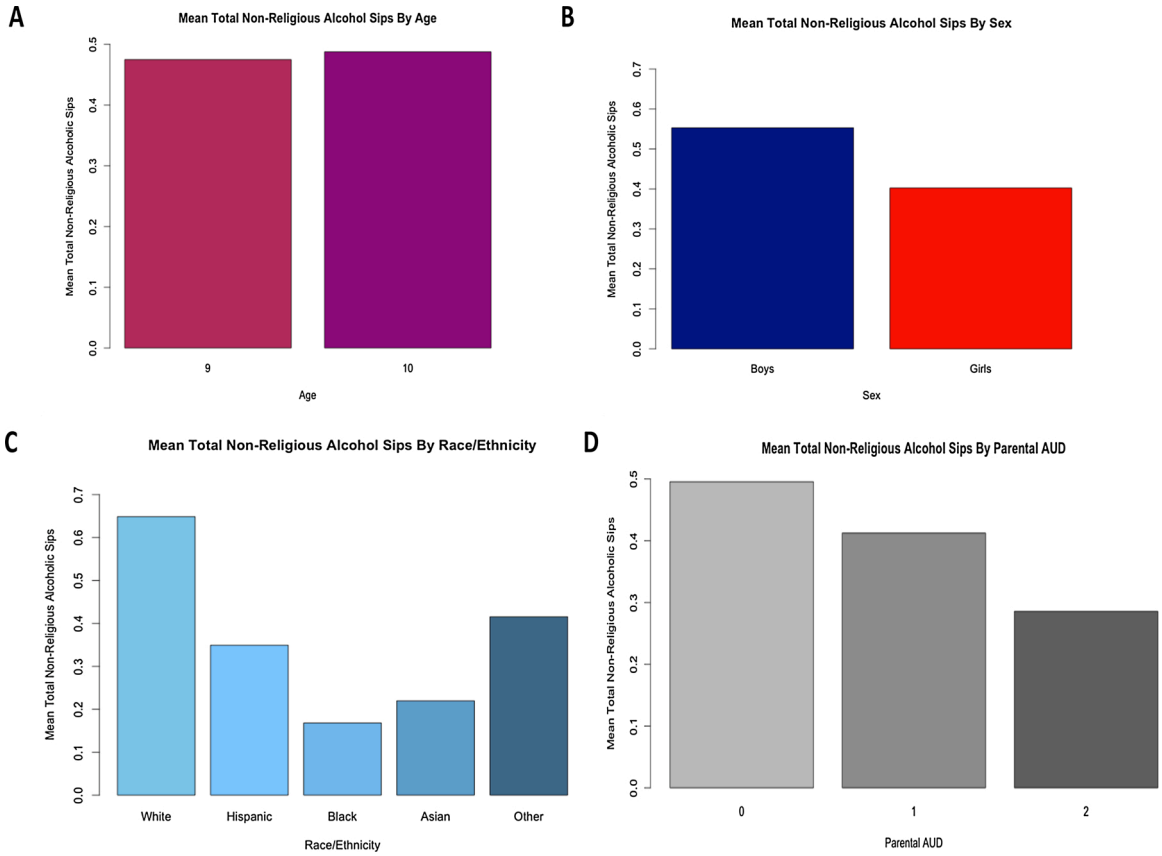

Fig. 4. Mean Total Times Sipped Alcohol (Non-Religious Context) in ABCD Study Participants at Baseline According to (A) Age, (B) Sex at Birth, (C) Race/Ethnicity, and (D) Parental AUD History Density.

2018)), here we found early associations between externalizing behaviors and total alcohol sipping occasions, although effect sizes were generally small. These early risk factors will need to be considered when prospectively examining the impact of early alcohol use on risk for problematic alcohol use trajectories in the ABCD Cohort as they age. Given that prior research links early alcohol sipping with risky adolescent drinking patterns and AUD development (Jackson, Barnett et al. 2015) (Grant and Dawson, 1997), even when the alcohol is provided by parents (Kaynak, Winters et al. 2014), it is recommended that healthcare providers discuss household alcohol rules and sipping behavior with parents and youth as young as seven to eight years old.

Recently ENDS use has grown in popularity in adolescents as young as 13–14 years old (Miech et al., 2019) (Johnston et al., 2020), although reports in younger cohorts are unavailable. In the current sample, few of the 9–10-year-olds reported any nicotine product use. Only 81 youth (0.68 %) reported trying a "puff" of a tobacco product such as ENDS or cigarettes. Consistent with the MTF Study reports (Miech et al., 2019), the most commonly first-used nicotine product was ENDS (57.3 %). The majority of youth did not continue to use the product after their first try (85 %), and the median age of first use was 7.5 years old. Thus, the ABCD cohort can be considered generally naïve to nicotine usage at baseline, although low-level early experimentation is starting as young as 6–7 years old, supporting prevention campaigns aimed at elementary-aged youth.

Notably, other SU (including cannabis use), was very rare in the 9- and 10-year-olds. Twelve youth (0.1 %) reported trying a cannabis product, most commonly smoking or vaping cannabis flower, although at least one youth reported trying other products (including blunts, cannabis edibles, cannabis concentrate or oil). The latter supports prior studies suggesting that measuring multiple routes of administration (e.g., vaping, smoking, ingestion) and types of cannabis product (e.g., flower, edibles, concentrates) (Streck, Hughes et al. 2019) is important, even in young cohorts. We also found that only a small fraction (<0.1 %) of youth reporting use of any other drugs of abuse. Findings support the ABCD Study aims to prospectively determine the impact of cannabis and other illicit drug use onset on neurocognitive and health outcomes, as the baseline cohort can be considered naïve to cannabis and other illicit-drugs.

Across several indices, males showed a riskier early substance experimentation pattern. They were significantly more likely to hear of nicotine, cannabis, and inhalant products. Despite being the same age, boys were more likely to use caffeine, consume a greater caffeine dose, sip alcohol, have greater non-religious alcohol sipping occasions, drink a full drink of alcohol, and try a nicotine or cannabis product compared to girls. Notably, effect sizes for these findings were generally small at this time-point, meaning sex differences at baseline may be considered subtle. Further, sex differences in caffeine use and alcohol sipping occasions were no longer significant in the multivariable analysis after accounting for other demographics, externalizing behaviors, and parental AUD or SUD. Still, these findings support prior studies showing increased risk of alcohol sipping in boys (Donovan, 2007) and suggest that future longitudinal SU analyses with the ABCD cohort need to carefully consider sex differences.

Potential limitations of the current study should be considered. Substance use was based on self-report and the current study did not discuss toxicology findings primarily due to low availability at baseline; toxicology collection is increased at follow-up time-points and will be integrated into NDA 3.0/4.0 data releases. For this analysis, the aims were to provide a detailed description of the SU patterns reported by youth enrolled in the ABCD Study at the baseline session to inform the broad scientific community as they plan their longitudinal analyses; therefore, demographic corrections were not employed. Several other

potential risk and protective factors were not analyzed here; more thorough examination of broad risk factors linked with early caffeine use and alcohol sipping are future directions (e.g., for a recent analysis examining personality factors associated with sipping, see (Watts, Wood et al. 2020). Finally, although the ABCD Study is a national, diverse study, it cannot be considered fully nationally-representative (Compton, Dowling et al. 2019).

In conclusion, youth who participated at the baseline time-point of the ABCD Study can be considered relatively substance-naïve with low-levels of caffeine use and alcohol sipping experimentation. Ongoing longitudinal assessment of these domains over a period of ten years in a socio-demographically diverse, nationwide sample of youth presents an unprecedented opportunity to examine the risk and protective factors influencing the onset, trajectories and sequela of SU, the impact of SU on neurocognitive and brain development, health and psychosocial outcomes, and to further understand the timing and interactive relationship between SU and psychopathology in youth that live in the United States.

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Declaration of Competing Interest

Martin Paulus is an adviser to Spring Care (New York City, NY, USA), a behavioral health startup. He has received royalties for an article about methamphetamine in UpToDate (Wolters Kluwer; Waltham, MA, USA).

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Susan R.B. Weiss and her husband own stock in Merck and GE, respectively.

Marilyn A. Huestis is a consultant for PinneyAssociates, Canopy Health Innovations, and AlgometRx.

Damien A. Fair and Nico U.F. Dosenbach are patent holders on the Framewise Integrated Real-Time Motion Monitoring (FIRMM) software and co-founders of Nous Imaging Inc. The nature of this financial interest and the design of the study have been reviewed by two committees at Oregon Health and Science University and Washington University School of Medicine. They have put in place plans to help ensure that this research study is not affected by the financial interests.

Anders M. Dale reports that he is a Founder of and holds equity in CorTechs Labs, Inc., and serves on its Scientific Advisory Board. He is a member of the Scientific Advisory Board of Human Longevity, Inc., and receives funding through research grants with General Electric Healthcare. The terms of these arrangements have been reviewed by and approved by the University of California, San Diego in accordance with its conflict of interest policies.

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