**Associations of arts and cultural engagement with substance use trajectories in adolescence and early adulthood: a latent growth curve analysis of the Add Health cohort**

**Meg E Fluharty[1], Feifei Bu[1], Jessica K Bone[1], Jill K Sonke[2], Daisy Fancourt[1], Elise Paul[1]**

1. Research Department of Behavioural Science and Health, Institute of Epidemiology & Health, University College London, London, UK

2. Center for Arts in Medicine, University of Florida, Gainesville, Florida, US

**Abstract**

*Introduction.* Substance use (e.g., alcohol, marijuana, tobacco) is common during adolescence and may lead to a number of long-term negative outcomes (e.g., poor mental health). It is therefore important to explore factors that reduce the risk of engaging in these potentially harmful behaviours. Extracurricular activities (i.e., how people spend their free time) are known to be effective in reducing the risk of engaging in substance use, but the specific effects of arts and cultural engagement are less known.

*Methods.* Data were from the first four waves (1994-2008) of the National Longitudinal Study of Adolescent to Adult Health (ages 12-17 years). Arts and cultural engagement were measured at wave 1 (1994) by (i) the number of arts and culture groups engaged in and (ii) the weekly frequency of arts and culture related hobbies. Substance use was measured using three binary indicators of any past month alcohol intoxication, marijuana, and tobacco use measured at waves 1 to 4. Latent growth curve modelling was used to examine associations between arts and cultural engagement (group participation and weekly hobbies) at wave 1 and trajectories of past month alcohol intoxication, marijuana use, and tobacco use over waves 1 to 4. Analyses accounted for sociodemographic covariates.

*Results.* At wave 1, participating in more arts and cultural groups was associated with lower concurrent likelihood of being intoxicated by alcohol and using tobacco. However, longitudinally, differences in likelihoods began to narrow across waves until there was no difference by wave 4. There was no association with marijuana use. Similar results were found for engagement in hobbies; adolescents who participated in more weekly hobbies were less likely to have used any of the three substances concurrently, although over time, the differences between the groups narrowed. However, there was some evidence that the differences persisted across waves when using a less stringent (weekly) alcohol intoxication variable.

*Conclusions.* Overall, this research confirms associations between arts and cultural engagement and substance use at a population level amongst adolescents in the US. Actively engaging in arts and cultural activities is associated with reduced risk of concurrent substance use suggesting a potential protective relationship. However, this protection attenuates over time. As we only examined arts and cultural activities at one time point, whether sustained engagement in these activities differentially influences the risk of substance use requires further investigation.

**Keywords**: arts, culture, hobbies, substance use, alcohol, tobacco, marijuana, adolescence

**Introduction**

Adolescence is a developmental period characterised by important cognitive, social, emotional, and neurobiological changes that can result in increased susceptibility to engaging in risk behaviours such as alcohol and substance use (1,2). For example, during this period of roughly ages 12 to 18, adolescents begin to develop their self-identity and learn to navigate their way through psychological challenges and stressors (3). Substance use can become a maladaptive coping strategy for dealing with stressors (4). Adolescents also begin to place increasing importance upon peer groups, thus becoming increasingly susceptible to peer influence, and substance use may be normalised (4,5). Neurological changes during this period such as the restructuring of the dopaminergic reward system in the brain can also result in increased sensation seeking (2,4,6). For young people who do experiment with alcohol and substance use, this experimentation (if repeated) can result in changes in nervous system and brain chemistry affecting reward systems and further increasing the desire to engage in such risk-taking behaviours (2,4). Substance use is common during adolescence in the United States, with 29% of high school students reporting past month alcohol and 22% marijuana use (7), and 37% tobacco use (8). Unfortunately, this can be detrimental for a range of later outcomes, as adolescent substance use is associated with a number of negative outcomes including risk of developing substance use disorder (9), poor mental health (9,10), involvement in criminalised behaviours (9), and lower educational attainment (9). This demonstrates the need to identify easily accessible risk reduction strategies.

Engagement in extracurricular activities (i.e., organised sports outside of school time) has generally been found to be beneficial in reducing the risk of substance use in adolescence (11–14). One category of extracurricular activities, arts and cultural engagement, is known to be associated with a range of positive social, mental health, and wellbeing outcomes in adolescence (15).

Further, arts based interventions (i.e., drama, storytelling, song writing, and interactive video drama) have been shown to be effective in reducing substance use in adolescence in small-scale intervention studies (16–18). Previous observational studies have also suggested that arts and cultural engagement may be beneficial as a risk reduction strategy for substance use in adults and adolescents (19,20). For example, a quasi-experimental study of a programme for 11-15-year-olds involving games, music, and storytelling found decreases in alcohol and marijuana use in the treatment group (21). Similarly, theatre and drama programmes have been found to be associated with lower levels of illicit drug use in high-school students (22,23) and young adults (24). However, most previous studies have been limited in that they have only included a single arts or cultural activity (22,25), a single substance use outcome (22), small and unrepresentative samples (23,26), or were cross-sectional (19,22).

Additionally, from the current literature, it is difficult to determine whether any frequency of arts or cultural engagement is effective in reducing risk of substance use, or if this depends on the level of engagement (11). Finally, it is unknown how long, if at all, any risk reduction lasts. That is, is engagement in arts and cultural activities only protective as adolescents are concurrently actively engaged, or is the reduced risk preserved over time?

The current study addressed these limitations by examining whether engagement in arts and cultural activities in adolescence were associated with substance use, including alcohol, marijuana, and tobacco, the three most commonly consumed substances amongst adolescents in the United States (US) (27). We first examined concurrent associations of arts and cultural engagement with substance use during adolescence, and secondly explored whether any relationships persisted longitudinally. We

used latent growth curve modelling to examine these associations from the first four waves (1994-2008) of the National Longitudinal Study of Adolescent to Adult Health (Add Health).

**Methods**

***Sample***
Participants were drawn from the National Longitudinal Study of Adolescent to Adult Health (Add Health); a longitudinal study of a nationally representative sample of adolescents who were in grades 7-11 (aged 12-17 years) during the 1994-95 school year, and have been followed for four waves (28). Add Health examines the causes of adolescent health and behaviour using social, behavioural, and biomedical approaches (28). Numerous contexts of the adolescent environment were sampled including school and family environments, parents, siblings, neighbourhoods, and communities which together provide indirect and direct measures of the adolescent period over time (28). The Add Health restricted-use data were used for this study, which contains the full data for all study participants.

At wave 1 (1994), there was adolescent and parent data for 14,016 participants. Of these adolescents, 10,481 also participated at wave 2 (1996), 8,127 at wave 3 (2001), and 8,334 at wave 4 (2008). After excluding participants with missing values in predictors our analytic sample comprised of 6,965 participants.

***Arts and cultural engagement exposures*** *(wave 1)*
*Arts and cultural group participation*
Adolescents were presented with a list of 32 school-based activities and asked "Are you participating/Do you plan to participate in the following clubs, organizations, and teams?" From the list, we selected 7 activities that represented arts and cultural engagement including: book club, drama club, band, cheerleading/dance, chorus or choir, orchestra, and [school] newspaper. Response options were binary representing engagement or not, and we created a categorical variable indicating participation in either 0, 1, or $\geq 2$ of the 7 activities.

*Weekly hobbies*
Adolescents were asked "During the past week, how many times did you do hobbies, such as collecting baseball cards, playing a musical instrument, reading, or doing arts and crafts?" with four response options of 'not at all', '1 or 2 times', '3 or 4 times', '5 or more times'.

***Substance use outcomes*** *(waves 1-4)*
*Alcohol*
Alcohol intoxication was measured at waves 1-4 by asking "During the past 12 months, on how many days have you been drunk or very high on alcohol." Response options were never, 1-2 days in the past 12 months, once a month or less, 2 or 3 days a month, 1-2 days a week, and 3-5 days a week. Responses were collapsed into less than monthly vs monthly.

Due to the largely socially accepted nature of alcohol use, a sensitivity alcohol intoxication variable was created collapsing responses into less than weekly vs weekly. This was intended to capture more routine alcohol intoxication as opposed to occasional normalised social circumstances (i.e., weddings, festivals, nights out).

*Marijuana*

Frequency of marijuana use was measured at waves 1-4 by asking "During the past 30 days, how many times did you use marijuana." Responses were collapsed into a binary indicator of any in the past month use vs none.

*Tobacco*
Frequency of tobacco use was measured at waves 1-4 by asking "During the past 30 days, how many days did you [smoke, use chewing tobacco]" and the highest response for either question was taken. Responses were collapsed into a binary indicator of past month use vs none.

**Covariates** *(wave 1)*
Ten sociodemographic factors from wave 1 were included as covariates: gender (male vs female), age (11-13 vs 14-16 vs >16 years), race/ethnicity (White vs Black/African American vs Asian/Pacific Islander, vs Other [including Hispanic and American Indian/Native American]), first language spoken at home (English vs Non-English), urbanicity of home location (urban vs suburban vs rural), parental education (less than high school vs high school vs some college vs college graduate), parental marital status (married vs unmarried [including divorced, separated, widowed, and never married]), household income (quartiles: $0-$20,999 vs $21,000-$38,999 vs $39,000-$60,000 vs >$60,000), parental smoking (yes vs no), and parental alcohol consumption (< weekly vs ≥ weekly).

**Statistical analyses**
Data were analysed using latent growth modelling (LGM). Given there were only four time points, we specified a linear growth model for the first three waves but allowed scores at the last wave to be estimated freely. The arts and cultural engagement exposures and time invariant covariates were included as predictors of the growth factors (intercept $\eta_0$ and slope $\eta_1$) (Figure 1). Models were fitted using the weighted least squares mean and variance adjusted (WLSMV) estimator because the outcome variables were categorical. The arts and cultural group participation and weekly hobbies exposures were run as separate models.

To account for the non-random nature of the sample, the data were weighted using Add Health's pre-derived longitudinal sample weights (29). All analyses were adjusted for sociodemographic factors and were conducted in Stata v16 (30) and MPlusV8 (27).

*Figure 1. Latent Growth Model Specifications*
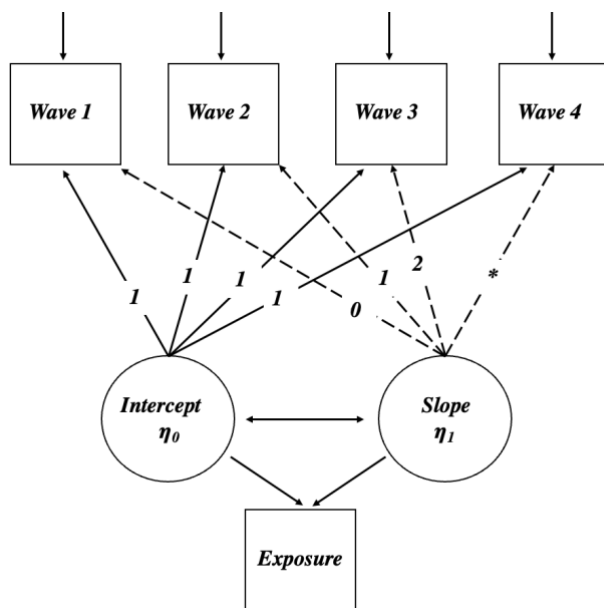


**Results**

In our weighted sample at wave 1, 54% were female, 60% were aged between 14 and 16 years and 51% were of white race/ ethnic background (Table 1, Supplementary Table S1). When asked if they were participating or planning to participate in arts or cultural groups, 65% of students reported no participation, 27% had participated in 1 activity, and 8% in ≥ 2 activities. Higher proportions of adolescents had engaged in arts and culture related hobbies: 33% participated 1-2 times weekly, 23% participated 3 to 4 times weekly, and 25% participated 5 or more times weekly. At wave 1, 26% of adolescents reported being intoxicated by alcohol at least once a month, 13% reported using marijuana in the past month, and 28% used tobacco in the past month.

*Table 1. Descriptive statistics of the explanatory variables at wave 1 (N = 6,965)*

| | | Unweighted | Weighted |
|---|---|---|---|
| **Arts and cultural group participation** | 0 Activities | 73.5% | 65.3% |
| | 1 Activity | 19.0% | 26.5% |
| | ≥2 Activities | 7.6% | 8.2% |
| **Weekly hobbies** | None at all | 19.0% | 19.0% |
| | 1 or 2 times weekly | 33.3% | 33.3% |
| | 3 or 4 times weekly | 23.0% | 23.0% |
| | ≥5 weekly | 24.7% | 24.7% |
| **Age at wave 1** | 11 to 13 | 14.4% | 17.0% |
| | 14 to 16 | 53.0% | 59.5% |
| | ≥16 | 32.5% | 23.5% |
| **Gender** | Male | 50.1% | 46.0% |
| | Female | 49.9% | 54.0% |
| **First language spoken at home** | English | 91.6% | 92.7% |
| | Non-English | 8.4% | 7.4% |
| **Parental marital status** | Married | 70.6% | 73.4% |
| | Unmarried | 29.4% | 26.6% |
| **Parental education** | Less than high school | 25.2% | 10.0% |
| | High school | 30.4% | 29.7% |
| | Some college | 22.2% | 21.1% |
| | College | 22.2% | 39.2% |
| **Household income** | $0-$20,000 | 24.1% | 21.7% |
| | $21,000-$38,999 | 25.3% | 25.9% |
| | $39,000-$60,000 | 29.2% | 29.9% |
| | Greater than $61,000 | 21.4% | 22.4% |
| **Race/ethnicity** | White | 64.5% | 51.2% |
| | Black/African American | 21.2% | 35.5% |
| | Asian/Pacific Islander | 5.3% | 5.1% |
| | Other | 9.0% | 8.2% |
| **Urbanicity of home location** | Urban | 36.8% | 9.3% |
| | Suburban | 38.1% | 63.2% |
| | Rural | 25.1% | 27.5% |
| **Parental alcohol consumption** | Less than weekly | 86.6% | 86.8% |
| | Weekly | 13.4% | 13.2% |
| **Parental smoking** | Non-smoker | 71.2% | 72.0% |
| | Smoker | 28.8% | 28.0% |

Note: 'Unmarried' marital status category includes: divorced, separated, widowed, and never married.
'Other' race/ethnicity category includes: Hispanic and American Indian/Native American.

*Concurrent associations*

At wave 1, the greater number of groups adolescents had participated in, the less likely they were to have concurrently been intoxicated by alcohol in the past month or used tobacco (Table 2, Figures 2-4, full model: Supplementary Table S2). There was no evidence of associations between arts and cultural group participation and marijuana use.

Additionally, at wave 1, the more frequently adolescents participated in hobbies, the less likely they were to have been intoxicated by alcohol or used tobacco or marijuana in the past month (Table 2, Figures 5-7, full model: Supplementary Table S2).

*Longitudinal associations*

The associations of arts and cultural groups with decreased past month alcohol intoxication and tobacco use were retained through to wave 2 but began to attenuate by wave 3 and by wave 4 there was little difference in users based on their wave 1 group participation (Table 3, Figures 2-4, full model: Supplementary Table S3). There was no evidence for associations between arts and cultural group participation and marijuana use.

Similarly, the associations of hobbies with alcohol intoxication, marijuana, and tobacco narrowed across time (Table 3, Figures 5-7, full model: Supplementary Table S3). Although these associations were still present by wave 2, they began to attenuate at wave 3 and by wave 4 there was little difference in those who were likely to have used alcohol or marijuana based on their wave 1 weekly hobbies. There was no evidence for associations among light marijuana or tobacco users.

*Table 2. Associations of the arts and cultural group and weekly hobbies participation predictors on the intercepts from the conditional latent growth models*

| | | Alcohol intoxication | | | Marijuana use | | | Tobacco use | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | *b* | *SE* | *p* | *b* | *SE* | *p* | *b* | *SE* | *p* |
| | | **Predictors of the intercept** | | | | | | | | |
| **Arts and cultural group participation** | 1 Activity *(vs 0 activities)* | **-0.43** | **0.13** | **0.001** | -0.56 | 0.30 | 0.064 | **-0.54** | **0.25** | **0.032** |
| | ≥2 Activities *(vs 0 activities)* | **-0.64** | **0.19** | **0.001** | -0.87 | 0.51 | 0.085 | **-1.23** | **0.51** | **0.015** |
| **Weekly hobbies** | 1 or 2 times weekly *(vs None at all)* | **-0.42** | **0.13** | **0.001** | -0.33 | 0.23 | 0.15 | **-0.66** | **0.30** | **0.026** |
| | 3 or 4 times weekly *(vs None at all)* | **-0.76** | **0.16** | **<0.001** | **-1.00** | **0.44** | **0.022** | **-1.10** | **0.44** | **0.013** |
| | ≥5 weekly *(vs None at all)* | **-0.99** | **0.18** | **<0.001** | **-1.10** | **0.48** | **0.021** | **-1.31** | **0.51** | **0.009** |

*Table 3. Associations of the arts and cultural group and weekly hobbies participation predictors on the slopes from the conditional latent growth models*

| | | Alcohol intoxication | | | Marijuana use | | | Tobacco use | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | *b* | *SE* | *p* | *b* | *SE* | *p* | *b* | *SE* | *p* |
| | | **Predictors of the slope** | | | | | | | | |
| **Arts and cultural group participation** | 1 Activity *(vs 0 activities)* | **0.22** | **0.06** | **<0.001** | 0.16 | 0.10 | 0.118 | 0.16 | 0.09 | 0.070 |
| | ≥2 Activities *(vs 0 activities)* | **0.35** | **0.10** | **<0.001** | 0.43 | 0.24 | 0.079 | **0.53** | **0.21** | **0.013** |
| **Weekly hobbies** | 1 or 2 times weekly *(vs None at all)* | **0.20** | **0.06** | **0.001** | 0.09 | 0.10 | 0.371 | 0.17 | 0.09 | 0.070 |
| | 3 or 4 times weekly *(vs None at all)* | **0.39** | **0.08** | **<0.001** | **0.37** | **0.15** | **0.017** | **0.32** | **0.12** | **0.011** |
| | ≥5 weekly *(vs None at all)* | **0.48** | **0.09** | **<0.001** | **0.42** | **0.17** | **0.013** | **0.43** | **0.15** | **0.004** |

## Figure 2. Arts and cultural group participation and alcohol intoxication



0 Clubs  1 Club  ≥2 Clubs
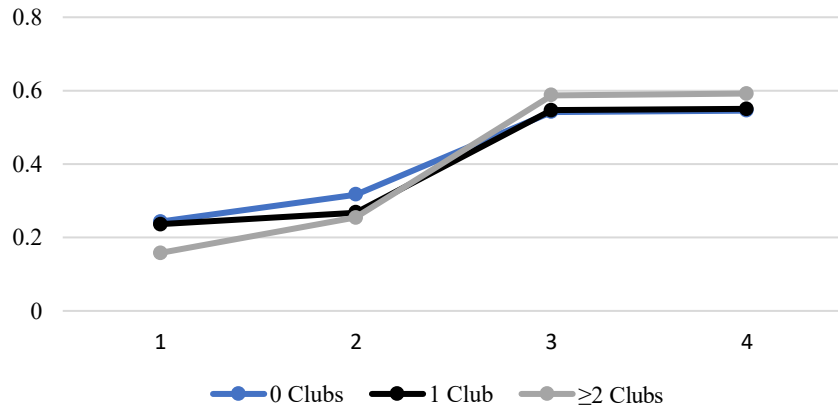
## Figure 3. Arts and cultural group participation and marijuana use



0 Clubs  1 Club  ≥2 Clubs
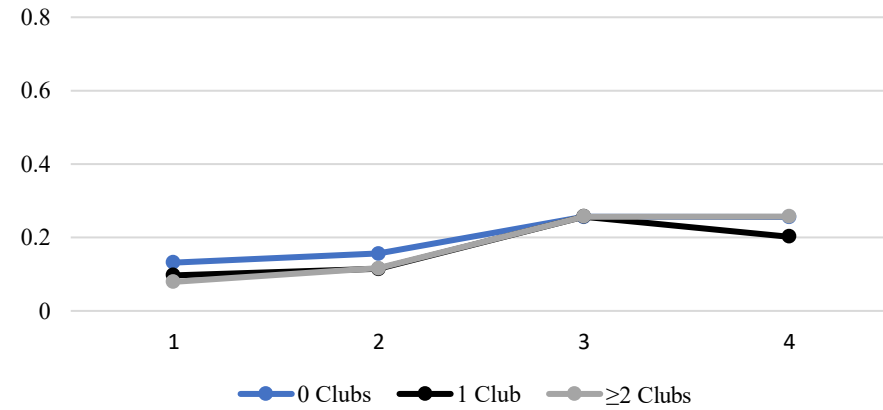
## Figure 4. Arts and cultural group participation and tobacco use
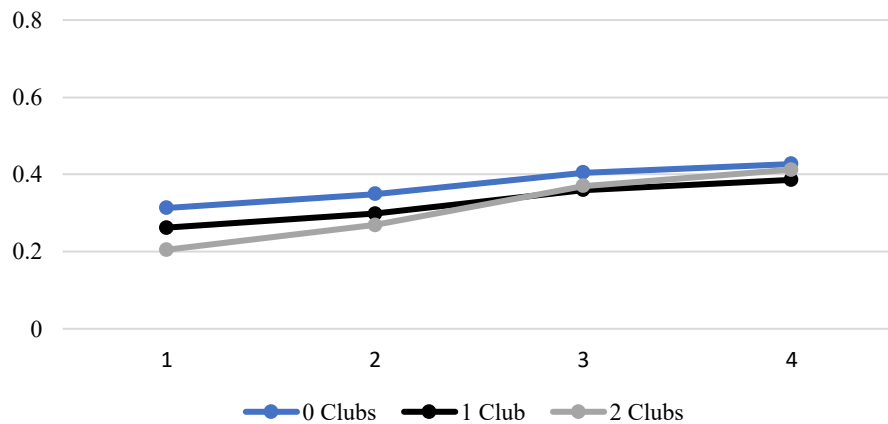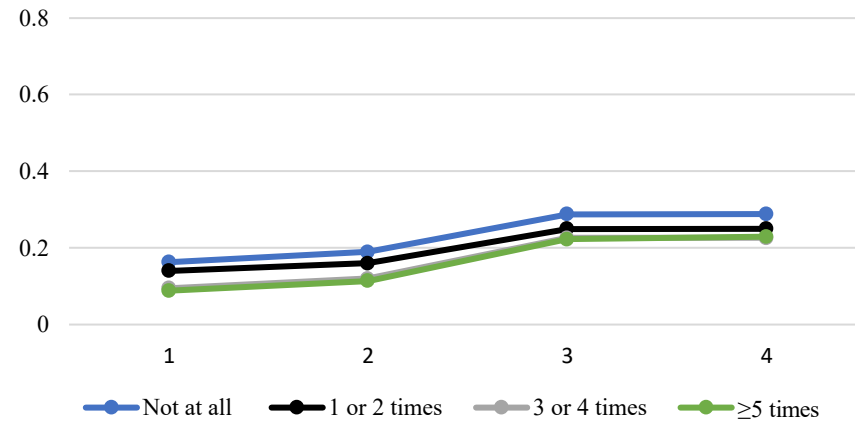


0 Clubs  1 Club  2 Clubs

Note: Figures 2-3 use data from the Add Health cohort Waves 1-4.
Wave 1 [1994-95] ages: 12-19; Wave 2 [1996] ages 13-20; Wave 3 [2001-02] ages: 18-26; Wave 4 [2008-09] ages: 24-32

*Figure 5. Weekly hobbies and alcohol intoxication*
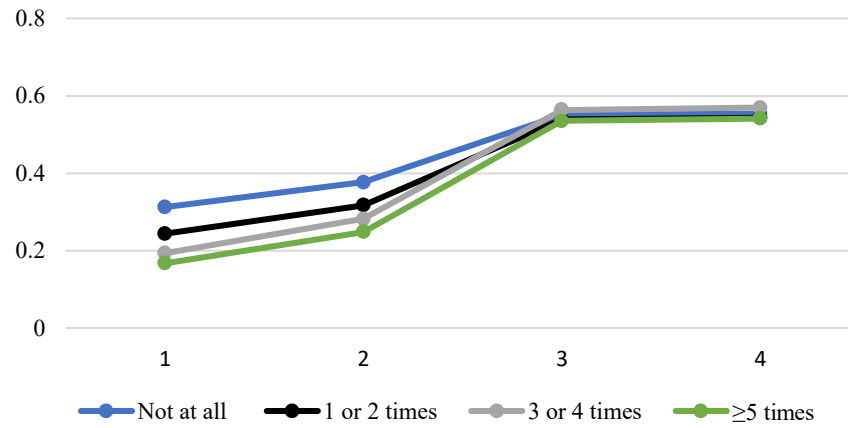

*Figure 6. Weekly hobbies and marijuana use*


*Figure 7. Weekly hobbies and tobacco use*

Note: Figures 2-3 use data from the Add Health cohort Waves 1-4.
Wave 1 [1994-95] ages: 12-19; Wave 2 [1996] ages 13-20; Wave 3 [2001-02] ages: 18-26; Wave 4 [2008-09] ages: 24-32
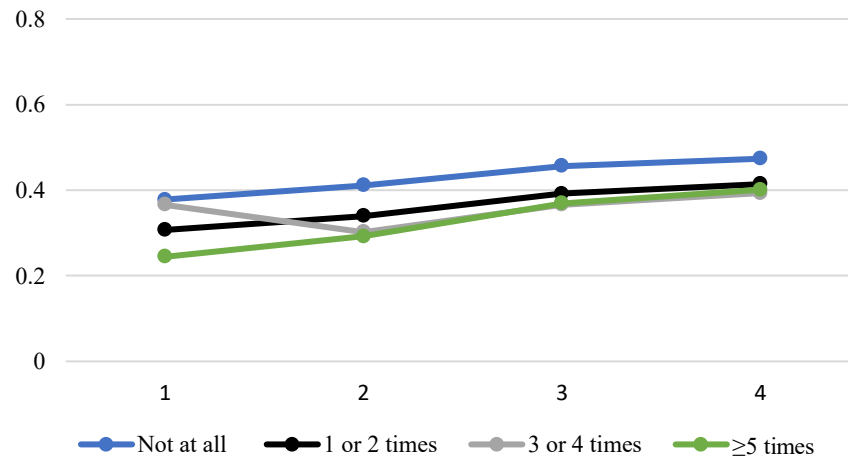
*Sensitivity analysis: weekly alcohol intoxication*

At wave 1, adolescents participating in ≥2 clubs, and a greater number of weekly hobbies were less likely to have concurrently been intoxicated by alcohol in the past week (Table 4, Figures 8-9, full model: Supplementary Table S4).

The associations of group participation with weekly alcohol intoxication persisted until wave 2 but attenuated by wave 3 (Table 4, Figure 8, full model: Supplementary Table S4). However, for weekly hobbies, the associations persisted across all four waves, particularly the difference between those engaging in 0 hobbies versus all other participation categories (Table 4, Figure 9, full model: Supplementary Table S4).

*Table 4. Associations of the arts and cultural group and weekly hobbies participation predictors on the intercept and slopes from the conditional latent growth models*

| | | Weekly alcohol intoxication | | | | | |
|---|---|---|---|---|---|---|---|
| | | *b* | *SE* | *p* | *b* | *SE* | *p* |
| | | **Predictors of the intercept** | | | **Predictors of the slope** | | |
| **Arts and cultural group participation** | 1 Activity *(vs 0 activities)* | -0.51 | 0.27 | 0.057 | 0.19 | 0.16 | 0.215 |
| | ≥2 Activities *(vs 0 activities)* | **-1.58** | **0.55** | **0.004** | **0.79** | **0.31** | **0.011** |
| **Weekly hobbies** | 1 or 2 times weekly *(vs None at all)* | **-0.85** | **0.26** | **0.001** | 0.23 | 0.15 | 0.122 |
| | 3 or 4 times weekly *(vs None at all)* | **-1.29** | **0.31** | **<0.001** | **0.45** | **0.17** | **0.009** |
| | ≥5 weekly *(vs None at all)* | **-1.24** | **0.30** | **<0.001** | **0.52** | **0.17** | **0.003** |



*Figure 8. Group participation and alcohol intoxication*
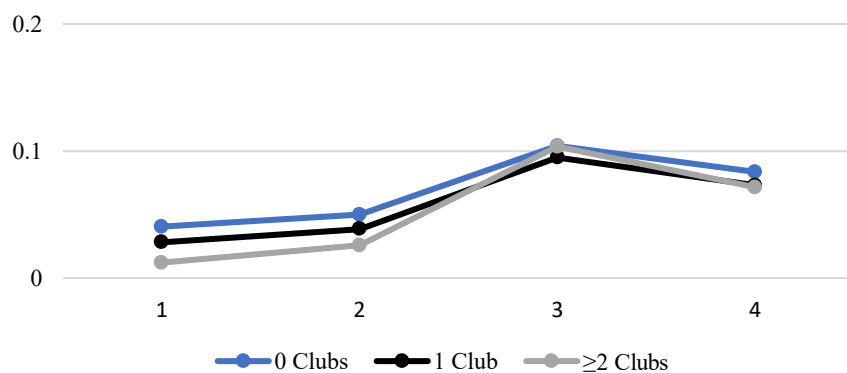


*Figure 9. Weekly hobbies and alcohol intoxication*
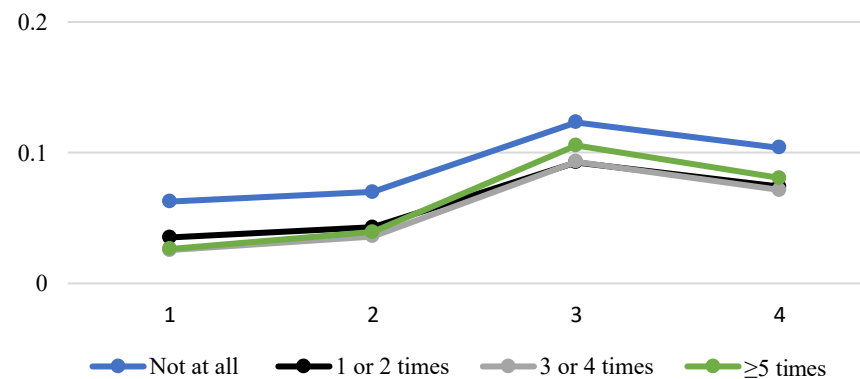
Note: Figures 2-3 use data from the Add Health cohort Waves 1-4.
Wave 1 [1994-95] ages: 12-19; Wave 2 [1996] ages 13-20; Wave 3 [2001-02] ages: 18-26; Wave 4 [2008-09] ages: 24-32

**Discussion**

This research builds on previous evidence that positions arts and cultural engagement as a health behaviour (15), which has not clearly been investigated in the US, and that equitable acess to the arts is a social determinate of health (31,32). This current study examined whether arts and cultural engagement was associated with longitudinal trajectories of the most commonly used substances (alcohol, marijuana, and tobacco) among US adolescents. During adolescence, participating in (or planning on participating in) more arts and cultural groups was associated with a lower concurrent likelihood of alcohol intoxication and tobacco use even after accounting for sociodemographic factors. Over the following 14 years, whilst some associations remained for a few years, the differences in likelihood of past month alcohol intoxication and tobacco use narrowed across all individuals regardless of their arts and cultural group engagement. Similar results were found for those who engaged more frequently in hobbies at wave 1 with similar predicated rates of past month alcohol intoxication and marijuana use among all individuals by 14-year follow-up. However, when applying a more stringent threshold for "frequent alcohol intoxication" of weekly vs monthly (to isolate repeated over-use of alcohol from drinking for special occasions), the protective associations for hobbies persisted for the full follow-up. Overall, these results show that concurrent engagement in arts and cultural activities is associated with a reduced risk of substance use, although this relationship may attenuate over time. The findings could indicate a protective causal effect of arts and cultural engagement on substance use (albeit one that diminishes over time), but they may also indicate reverse causality (whereby the presence of even earlier substance use may have affected arts and cultural engagement) or reflect the presence of a third factor that could determine both arts engagement and substance use. We consider all of these potential explanations below.

Considering the first of these potential explanations first, in which our findings display a concurrent protective effect of arts and cultural engagement on substance use. This is supported by past intervention studies, which have also demonstrated that art-based interventions are effective in reducing substance use (33). For example, music based interventions were associated with decreased cravings (17) and increase treatment motivation (33) within a detoxification unit. Further, there is strong evidence of causal associations of the arts on several mechanisms underlying substance use including development of prosocial behaviours, positive coping skills, and self-identify (15). So causal effects are mechanistically plausible. Notably, we still observed evidence of a protective association despite controlling for a wide range of confounders including sociodemographic factors and parental substance use. We also found that associations persisted for alcohol intoxication for 14-year follow-up when applying a more stringent threshold of weekly vs monthly. This more stringent threshold was intended to isolate repeated over-use of alcohol from drinking for special occasions: whilst any drinking in 12-18 year olds is illegal in the US, amongst adults, one in 4 adults in the US reportedly engages in binge drinking once a month (34). This could explain the attenuation of findings when applying a monthly threshold compared to when applying the stricter weekly threshold. Thus, these findings could augment the existing body of experimental and observational evidence on a longitudinal relationship between arts and cultural engagement and substance use.

However, for other substance use variables (marijuana and tobacco), over time we found potential protective benefits for substance use generally appeared to fade. Due to the data available, we were unable to determine which participants continued to engage in the arts past wave 1. But it is possible that art and cultural engagement is a "perishable commodity" in relation to substance use. This has been proposed in previous work on arts and cultural engagement and outcomes including wellbeing (35) and self-reported health (36). These studies suggest that if the link is indeed causal and arts and

cultural participation is positively influencing health, then frequent replenishment is required (36). Although in the current study, the effects of arts and cultural engagement sustained into wave 2, these associations began to disappear by waves 3 and 4. Therefore, there is some degree of retention before the effects are lost, but this is also not entirely surprising given adolescent behaviours may be superseded by later behaviours.

It is also possible that the results presented here are indicative of reverse causality. Some studies do show evidence that engagement with the arts is associated with increased substance use, however these tend to be context specific or restricted to some populations. For example, music festival attendees are known to use more substances compared to nonattenders (37,38). While, professional ballet dancers were more likely to be tobacco users, compared to other arts performers, although the motivations for this were to increase metabolism to maintain low body weight due to extreme industry standards (39). Additionally, there is some evidence suggesting prodromal effects as those engaging in substance use by adolescence may have already been trying other risky behaviours such as sexual activity, dangerous driving, and antisocial behaviour (41). Finally, there may be additional confounders not already included in the model. For example peer influence is known to be associated with both leisure activities and substance use (19). Research examining peer networks within organised activities indicates that participating in activities with peers whom use substances subsequently increases the risk of alcohol and tobacco use (19,42). However, this research has generally examined team/ sports activities due to the teamwork ecosystem developed (19,42) and not examined in the context of arts and cultural participation. Additionally, there are known associations between the built environment, poverty, alcohol/ tobacco and food sales, and health outcomes (43,44).

There are a number of strengths to the current study. Add Health is a large nationally representative cohort study with rich data collected across a number of waves (28). Therefore, we were able to analyse repeated data on three systematically collected measures of substance use (alcohol intoxication, marijuana use, and tobacco use), as well as adjusting for a range of sociodemographic covariates. Additionally, there were multiple questions which allowed us to derive and compare two different arts and cultural exposures at wave 1 (number of activities, and frequency of hobbies). However, it should be noted that the arts and cultural group participation variable was based upon both participation and planned participation. Therefore, it is possible this variable is subject to reporting bias, as we do not know the percentage of adolescents who followed through on potential "planned" participation. Additionally, there are a number of other limitations of the study to consider. All our substance use variables were self-reported as opposed to biologically verified, which may be subject to bias (45). Similarly, we only examined past month use of tobacco and marijuana, and it is important to note this variable does not represent an 'age of onset'. It is therefore possible participants may have engaged in substances earlier in their lives but not in the timeframe they were asked about. Additionally, as with all cohort studies, we were limited by the demographic categories available in the Add Health dataset. For example, we recognise that gender (male/female) and language spoken at home (English/non-English) are not binary constructs, even though we had to treat them as such. Future cohort studies must collect more detailed demographic data to ensure all individuals are equally and accurately represented. Similarly, the small numbers in non-White groups created an overly simple race/ethnicity variable, which conflates experiences across diverse racial/ethnic groups. Future cohort studeis must include more diverse samples and collect more detailed data on race/ethnicity in order to be truly representative. For example, future papers with proper representation could examine current concerns around native youth in North America and early-onset substance use (46,47).

Our results display an association between participation in arts and cultural activities and reduced likelihood of substance use present concurrently and at year follow-up amongst US adolescents. This association was present even when controlling for numerous confounders but diminished by 7 and 14 year follow-up. However, when we used a more stringent criteria for alcohol intoxication, we found these effects lasted for the whole 14-year follow-up. Overall, this research confirms associations between arts and cultural engagement and substance use at a population level amongst adolescents in the US. However, it suggests the need for further research including to disentangle the potential differential effects on different types of substances and to confirm causality. Nonetheless, given the presence of plausible causal pathways through which arts and cultural engagement could lead to differences in substance use behaviours and the clear potential implications of these findings to adolescent leisure and educational provision, such research is encouraged.

**References**

1. Sturman DA, Moghaddam B. The neurobiology of adolescence: Changes in brain architecture, functional dynamics, and behavioral tendencies. Neuroscience & Biobehavioral Reviews. 2011 Aug 1;35(8):1704–12.

2. Conrod PJ, Nikolaou K. Annual Research Review: On the developmental neuropsychology of substance use disorders. J Child Psychol Psychiatry. 2016 Mar;57(3):371–94.

3. Crocetti E. Identity dynamics in adolescence: Processes, antecedents, and consequences. European Journal of Developmental Psychology. 2018 Jan 2;15(1):11–23.

4. MacKillop J, Ray LA. The etiology of addiction: A contemporary biopsychosocial approach. In: Integrating psychological and pharmacological treatments for addictive disorders: An evidence-based guide. New York, NY, US: Routledge/Taylor & Francis Group; 2018. p. 32–53.

5. Allen JP, Loeb EL, Narr RK, Costello MA. Different factors predict adolescent substance use versus adult substance abuse: Lessons from a social-developmental approach. Development and Psychopathology. 2021;33(3):792–802.

6. Kim-Spoon J, Kahn RE, Lauharatanahirun N, Deater-Deckard K, Bickel WK, Chiu PH, et al. Executive functioning and substance use in adolescence: Neurobiological and behavioral perspectives. Neuropsychologia. 2017 Jun 1;100:79–92.

7. Jones CM, Clayton HB, Deputy NP, Roehler DR, Ko JY, Esser MB, et al. Prescription Opioid Misuse and Use of Alcohol and Other Substances Among High School Students — Youth Risk Behavior Survey, United States, 2019. MMWR Suppl. 2020;69(1):38–46.

8. Creamer MR, Everett Jones S, Gentzke AS, Jamal A, King BA. Tobacco Product Use Among High School Students — Youth Risk Behavior Survey, United States, 2019. MMWR Suppl. 2020;69(1):56–63.

9. Hall WD, Patton G, Stockings E, Weier M, Lynskey M, Morley KI, et al. Why young people's substance use matters for global health. The Lancet Psychiatry. 2016;3(3):265–79.

10. Fluharty M, Taylor AE, Grabski M, Munafò MR. The association of cigarette smoking with depression and anxiety: a systematic review. Nicotine & Tobacco Research. 2016;19(1):3–13.

11. Farb AF, Matjasko JL. Recent advances in research on school-based extracurricular activities and adolescent development. Developmental Review. 2012;32(1):1–48.

12. Meier A, Hartmann BS, Larson R. A Quarter Century of Participation in School-Based Extracurricular Activities: Inequalities by Race, Class, Gender and Age? J Youth Adolescence. 2018 Jun 1;47(6):1299–316.

13. Kenney A, Dennis CB. Environmental paths that inform adolescent substance use prevention. Journal of Human Behavior in the Social Environment. 2019;29(7):897–908.

14. Adachi-Mejia AM, Gibson Chambers JJ, Li Z, Sargent JD. The relative roles of types of extracurricular activity on smoking and drinking initiation among tweens. Acad Pediatr. 2014;14(3):271–8.

15. Fancourt D, Finn S, World Health Organization, Regional Office for Europe, Health Evidence Network. What is the evidence on the role of the arts in improving health and well-being?: a scoping review [Internet]. 2019 [cited 2020 Nov 25]. Available from: http://www.ncbi.nlm.nih.gov/books/NBK553773/

16. Pentz MA, Hieftje KD, Pendergrass TM, Brito SA, Liu M, Arora T, et al. A Videogame Intervention for Tobacco Product Use Prevention in Adolescents. Addict Behav. 2019 Apr;91:188–92.

17. Silverman MJ. Effects of group-based educational songwriting on craving in patients on a detoxification unit: A cluster-randomized effectiveness study. Psychology of Music. 2019 Mar 1;47(2):241–54.

18. Nelson A, Arthur B. Storytelling for Empowerment: Decreasing At-Risk Youth's Alcohol and Marijuana Use. Journal of Primary Prevention. 2003;24(2):169–80.

19. Fujimoto K, Valente TW. Alcohol peer influence of participating in organized school activities: A network approach. Health Psychology. 2013;32(10):1084–92.

20. Coto L. Extracurricular Activities and Substance Use Among Adolescents: A Test of Social Control and Social Learning Theory. Electronic Theses and Dissertations, 2004-2019 [Internet]. 2016 Jan 1; Available from: https://stars.library.ucf.edu/etd/5193

21. Nelson A, Arthur B. Storytelling for Empowerment: Decreasing At-Risk Youth's Alcohol and Marijuana Use. The Journal of Primary Prevention. 2003 Dec 1;24(2):169–80.

22. Quek L-H, White A, Low C, Brown J, Dalton N, Dow D, et al. Good choices, great future: An applied theatre prevention program to reduce alcohol-related risky behaviours during Schoolies. Drug and Alcohol Review. 2012;31(7):897–902.

23. Huang S-F, Zheng W-L, Liao J-Y, Huang C-M, Lin T-Y, Guo J-L. The effectiveness of a theory-based drama intervention in preventing illegal drug use among students aged 14–15 years in Taiwan. Health Education Journal. 2018 Jun 1;77(4):470–81.

24. Nyamathi A, Slagle A, Thomas A, Hudson A, Kahilifard F, Avila G, et al. Art Messaging to Engage Homeless Young Adults. Progress in Community Health Partnerships: Research, Education, and Action. 2011;5(1):7–7.

25. Huang S-F, Zheng W-L, Liao J-Y, Huang C-M, Lin T-Y, Guo J-L. The effectiveness of a theory-based drama intervention in preventing illegal drug use among students aged 14–15 years in Taiwan. Health Education Journal. 2018 Jun 1;77(4):470–81.

26. Barber BL, Eccles JS, Stone MR. Whatever Happened to the Jock, the Brain, and the Princess?: Young Adult Pathways Linked to Adolescent Activity Involvement and Social Identity. Journal of Adolescent Research. 2001 Sep 1;16(5):429–55.

27. Johnston LD, Miech RA, O'Malley PM, Bachman JG, Schulenberg JE, Patrick ME. Monitoring the Future National Survey Results on Drug Use, 1975-2019: Overview, Key Findings on Adolescent Drug Use [Internet]. Institute for Social Research. Institute for Social Research; 2020 [cited 2021 Jul 29]. Available from: https://eric.ed.gov/?id=ED604018

28. Harris KM, Halpern CT, Whitsel EA, Hussey JM, Killeya-Jones LA, Tabor J, et al. Cohort Profile: The National Longitudinal Study of Adolescent to Adult Health (Add Health). International Journal of Epidemiology. 2019 Oct 1;48(5):1415–1415k.

29. Chen P. Guidelines for Analyzing Add Health Data. 2014 [cited 2021 Jul 29]; Available from: https://cdr.lib.unc.edu/concern/articles/k0698990v?locale=en

30. Stata | FAQ: Citing Stata software, documentation, and FAQs [Internet]. [cited 2020 Dec 2]. Available from: https://www.stata.com/support/faqs/resources/citing-software-documentation-faqs/

31. Bone JK, Bu F, Fluharty ME, Paul E, Sonke JK, Fancourt D. Engagement in leisure activities and depression in older adults in the United States: Longitudinal evidence from the Health and Retirement Study. Social Science & Medicine. 2022 Feb 1;294:114703.

32. Fluharty M, Paul E, Bone J, Bu F, Sonke J, Fancourt D. Difference in predictors and barriers to arts and cultural engagement with age in the United States: A cross-sectional analysis using the Health and Retirement Study. PLOS ONE. 2021 Dec 20;16(12):e0261532.

33. Hohmann L, Bradt J, Stegemann T, Koelsch S. Effects of music therapy and music-based interventions in the treatment of substance use disorders: A systematic review. PLOS ONE. 2017 Nov 15;12(11):e0187363.

34. Alcohol Facts and Statistics | National Institute on Alcohol Abuse and Alcoholism (NIAAA) [Internet]. [cited 2022 Jan 17]. Available from: https://www.niaaa.nih.gov/publications/brochures-and-fact-sheets/alcohol-facts-and-statistics

35. Tymoszuk U, Perkins R, Spiro N, Williamon A, Fancourt D. Longitudinal Associations Between Short-Term, Repeated, and Sustained Arts Engagement and Well-Being Outcomes in Older Adults. The Journals of Gerontology: Series B. 2020 Aug 13;75(7):1609–19.

36. Johansson SE, Konlaan BB, Bygren LO. Sustaining habits of attending cultural events and maintenance of health: a longitudinal study. Health Promotion International. 2001 Sep 1;16(3):229–34.

37. Bijlsma L, Celma A, Castiglioni S, Salgueiro-González N, Bou-Iserte L, Baz-Lomba JA, et al. Monitoring psychoactive substance use at six European festivals through wastewater and pooled urine analysis. Science of The Total Environment. 2020 Jul 10;725:138376.

38. Lim MSC, Lim MSC, Hellard ME, Lim MSC, Hellard ME, Hocking JS, et al. A cross-sectional survey of young people attending a music festival: associations between drug use and musical preference. Drug and Alcohol Review. 2008 Jan 1;27(4):439–41.

39. Sekulic D, Peric M, Rodek J. Substance use and misuse among professional ballet dancers. Subst Use Misuse. 2010 Jul;45(9):1420–30.

40. Feldstein SW, Miller WR. Substance use and risk-taking among adolescents. Journal of Mental Health. 2006 Jan 1;15(6):633–43.

41. Luk JW, Worley MJ, Winiger E, Trim RS, Hopfer CJ, Hewitt JK, et al. Risky driving and sexual behaviors as developmental outcomes of co-occurring substance use and antisocial behavior. Drug and Alcohol Dependence. 2016 Dec 1;169:19–25.

42. Fujimoto K, Unger JB, Valente TW. A network method of measuring affiliation-based peer influence: assessing the influences of teammates' smoking on adolescent smoking. Child Dev. 2012 Apr;83(2):442–51.

43. Bernstein KT, Galea S, Ahern J, Tracy M, Vlahov D. The built environment and alcohol consumption in urban neighborhoods. Drug and Alcohol Dependence. 2007 Dec;91(2–3):244–52.

44. Farley SM, Maroko AR, Suglia SF, Thorpe LE. The Influence of Tobacco Retailer Density and Poverty on Tobacco Use in a Densely Populated Urban Environment. Public Health Rep. 2019 Mar 1;134(2):164–71.

45. Petróczi A, Nepusz T. Methodological considerations regarding response bias effect in substance use research: is correlation between the measured variables sufficient? Substance Abuse Treatment, Prevention, and Policy. 2011 Jan 18;6(1):1.

46. Maina G, Mclean M, Mcharo S, Kennedy M, Djiometio J, King A. A scoping review of school-based indigenous substance use prevention in preteens (7–13 years). Substance Abuse Treatment, Prevention, and Policy. 2020 Oct 1;15(1):74.

47. Trujillo CA, Obando D, Trujillo A. An examination of the association between early initiation of substance use and interrelated multilevel risk and protective factors among adolescents. PLOS ONE. 2019 Dec 11;14(12):e0225384.

**Supplementary Material**

*Table S1. Wave 1 substance use by arts and cultural participation*

| | | Arts and cultural group participation | | | Weekly hobbies | | | |
|---|---|---|---|---|---|---|---|---|
| | | 0 Activities | 1 Activity | ≥2 Activities | None at all | 1 or 2 times weekly | 3 or 4 times weekly | ≥5 weekly |
| **Alcohol intoxication** | Less than monthly or none | 81.1% | 87.9% | 88.7% | 77.1% | 83.2% | 85.5% | 85.3% |
| | Monthly | 18.9% | 12.1% | 11.3% | 22.9% | 16.8% | 14.5% | 14.8% |
| **Marijuana use** | No use | 84.1% | 89.9% | 90.3% | 80.2% | 85.7% | 88.2% | 88.0% |
| | Used in past month | 15.9% | 10.2% | 9.7% | 19.8% | 14.3% | 11.8% | 12.1% |
| **Tobacco use** | No use | 69.2% | 77.6% | 79.7% | 62.7% | 71.4% | 75.5% | 75.7% |
| | Used in past month | 30.9% | 22.4% | 20.3% | 37.4% | 28.6% | 24.5% | 24.4% |

*Table S2. Full Model. Associations of the arts and cultural group participation and weekly hobbies predictors on the intercepts from the conditional latent growth models*

| | | Alcohol intoxication | | | Marijuana use | | | Tobacco use | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | *b* | *SE* | *p* | *b* | *SE* | *p* | *b* | *SE* | *p* |
| | | **Predictors of the intercept** | | | | | | | | |
| **Arts and cultural group participation** | 1 Activity *(vs 0 activities)* | **-0.43** | **0.13** | **0.001** | -0.56 | 0.30 | 0.064 | **-0.54** | **0.25** | **0.032** |
| | ≥ 2 Activities *(vs 0 activities)* | **-0.64** | **0.19** | **0.001** | -0.87 | 0.51 | 0.085 | **-1.23** | **0.51** | **0.015** |
| **Age at wave 1** | 14 to 16 *(vs 11 to 13)* | **1.69** | **0.25** | **<0.001** | **1.66** | **0.75** | **0.027** | **1.60** | **0.59** | **0.007** |
| | > 16 *(vs 11 to 13)* | **2.67** | **0.37** | **<0.001** | **2.34** | **1.04** | **0.024** | **2.74** | **0.99** | **0.005** |
| **Gender** | Female *(vs Male)* | **0.21** | **0.10** | **0.024** | 0.29 | 0.21 | 0.165 | 0.15 | 0.15 | 0.342 |
| **First language spoken at home** | Non-English *(vs English)* | **-0.87** | **0.25** | **<0.001** | -1.31 | 0.68 | 0.054 | **-1.40** | **0.58** | **0.016** |
| **Parental marital status** | Unmarried* *(vs Married)* | **0.45** | **0.13** | **<0.001** | **1.01** | **0.46** | **0.027** | 0.18 | 0.18 | 0.315 |
| **Parental education** | High school *(vs Less than high school)* | -0.05 | 0.17 | 0.776 | 0.19 | 0.30 | 0.527 | 0.32 | 0.27 | 0.244 |
| | Some college *(vs Less than high school)* | 0.02 | 0.18 | 0.936 | 0.31 | 0.33 | 0.342 | 0.03 | 0.27 | 0.908 |
| | College *(vs Less than high school)* | -0.09 | 0.18 | 0.637 | 0.38 | 0.34 | 0.269 | 0.06 | 0.27 | 0.827 |
| **Household income** | $21,000-$38,999 *(vs $0-$20,000)* | 0.13 | 0.13 | 0.351 | 0.38 | 0.28 | 0.167 | 0.04 | 0.21 | 0.852 |
| | $39,000-$60,000 *(vs $0-$20,000)* | 0.08 | 0.14 | 0.59 | -0.06 | 0.25 | 0.81 | -0.37 | 0.25 | 0.136 |
| | Greater than $61,000 *(vs $0-$20,000)* | 0.22 | 0.16 | 0.179 | 0.60 | 0.37 | 0.108 | -0.14 | 0.25 | 0.574 |
| **Race/ethnicity** | Black/African American *(vs White)* | **-1.16** | **0.19** | **<0.001** | -0.41 | 0.28 | 0.133 | **-2.07** | **0.73** | **0.004** |
| | Asian/Pacific Islander *(vs White)* | **-0.62** | **0.26** | **0.015** | 0.01 | 0.41 | 0.984 | **-1.53** | **0.63** | **0.015** |
| | Other ** *(vs White)* | 0.04 | 0.17 | 0.808 | 0.96 | 0.51 | 0.062 | -0.53 | 0.34 | 0.114 |
| **Urbanicity of home location** | Suburban *(vs Urban)* | 0.19 | 0.11 | 0.089 | -0.04 | 0.18 | 0.845 | -0.04 | 0.17 | 0.804 |
| | Rural *(vs Urban)* | 0.10 | 0.12 | 0.382 | -0.25 | 0.22 | 0.253 | 0.29 | 0.20 | 0.149 |
| **Parental alcohol consumption** | Weekly *(vs Less than weekly)* | **0.57** | **0.14** | **<0.001** | 0.17 | 0.22 | 0.43 | 0.37 | 0.23 | 0.107 |
| **Parental smoking** | Smoker *(vs Non-Smoker)* | **0.58** | **0.12** | **<0.001** | **0.77** | **0.36** | **0.03** | **0.78** | **0.30** | **0.009** |
| | | | | | | | | | | |
| **Weekly hobbies** | 1 or 2 times weekly *(vs None at all)* | **-0.42** | **0.13** | **0.001** | -0.33 | 0.23 | 0.15 | **-0.66** | **0.30** | **0.026** |
| | 3 or 4 times weekly *(vs None at all)* | **-0.76** | **0.16** | **<0.001** | **-1.00** | **0.44** | **0.022** | **-1.10** | **0.44** | **0.013** |
| | ≥5 weekly *(vs None at all)* | **-0.99** | **0.18** | **<0.001** | **-1.10** | **0.48** | **0.021** | **-1.31** | **0.51** | **0.009** |
| **Age at wave 1** | 14 to 16 *(vs 11 to 13)* | **1.65** | **0.24** | **<0.001** | **1.59** | **0.68** | **0.019** | **1.61** | **0.61** | **0.008** |
| | >16 *(vs 11 to 13)* | **2.60** | **0.35** | **<0.001** | **2.23** | **0.93** | **0.016** | **2.74** | **1.01** | **0.007** |
| **Gender** | Female *(vs Male)* | 0.06 | 0.09 | 0.49 | 0.09 | 0.16 | 0.576 | -0.07 | 0.14 | 0.609 |
| **First language spoken at home** | Non-English *(vs English)* | **-0.82** | **0.24** | **0.001** | **-1.21** | **0.61** | **0.048** | **-1.37** | **0.58** | **0.019** |
| **Parental marital status** | Unmarried* *(vs Married)* | **0.43** | **0.12** | **<0.001** | **0.96** | **0.41** | **0.02** | 0.18 | 0.19 | 0.321 |
| **Parental education** | High school *(vs Less than high school)* | -0.07 | 0.17 | 0.677 | 0.14 | 0.28 | 0.621 | 0.28 | 0.27 | 0.301 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Some college (*vs Less than high school*) | 0.01 | 0.18 | 0.979 | 0.28 | 0.31 | 0.366 | 0.02 | 0.27 | 0.951 |
| | College (*vs Less than high school*) | -0.07 | 0.18 | 0.674 | 0.36 | 0.32 | 0.262 | 0.05 | 0.27 | 0.843 |
| **Household income** | $21,000-$38,999 (*vs $0-$20,000*) | 0.14 | 0.13 | 0.276 | 0.38 | 0.26 | 0.152 | 0.06 | 0.21 | 0.765 |
| | $39,000-$60,000 (*vs $0-$20,000*) | 0.12 | 0.14 | 0.378 | -0.02 | 0.24 | 0.949 | -0.32 | 0.24 | 0.183 |
| | Greater than $61,000 (*vs $0-$20,000*) | 0.27 | 0.16 | 0.097 | 0.61 | 0.35 | 0.087 | -0.09 | 0.24 | 0.727 |
| **Race/ethnicity** | Black/African American (*vs White*) | **-1.19** | **0.19** | **<0.001** | -0.46 | 0.27 | 0.093 | **-2.14** | **0.77** | **0.005** |
| | Asian/Pacific Islander (*vs White*) | **-0.60** | **0.25** | **0.014** | 0.00 | 0.40 | 0.996 | **-1.54** | **0.64** | **0.017** |
| | Other (*vs White*) | 0.00 | 0.17 | 0.982 | 0.88 | 0.46 | 0.057 | -0.58 | 0.35 | 0.1 |
| **Urbanicity of home location** | Suburban (*vs Urban*) | 0.20 | 0.11 | 0.066 | -0.02 | 0.18 | 0.906 | -0.01 | 0.17 | 0.942 |
| | Rural (*vs Urban*) | 0.08 | 0.11 | 0.461 | -0.25 | 0.21 | 0.231 | 0.28 | 0.20 | 0.167 |
| **Parental alcohol consumption** | Weekly (*vs Less than weekly*) | **0.58** | **0.13** | **<0.001** | 0.19 | 0.21 | 0.365 | 0.40 | 0.24 | 0.092 |
| **Parental smoking** | Smoker (*vs Non-Smoker*) | **0.59** | **0.12** | **<0.001** | **0.77** | **0.33** | **0.021** | **0.81** | **0.32** | **0.01** |

*Note: 'Unmarried' marital status category includes: divorced, separated, widowed, and never married.*

*'Other' race/ethnicity category includes: Hispanic and American Indian/Native American.*

***Table S3. Full Model. Associations of the arts and cultural group participation and weekly hobbies predictors on the slopes from the conditional latent growth models***

| | | Alcohol intoxication | | | Marijuana use | | | Tobacco use | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | *b* | *SE* | *p* | *b* | *SE* | *p* | *b* | *SE* | *p* |
| | | **Predictors of the intercept** | | | | | | | | |
| **Arts and cultural group participation** | 1 Activity *(vs 0 activities)* | **-0.42** | **0.13** | **0.001** | -0.33 | 0.23 | 0.15 | **-0.66** | **0.30** | **0.026** |
| | ≥ 2 Activities *(vs 0 activities)* | **-0.76** | **0.16** | **<0.001** | **-1.00** | **0.44** | **0.022** | **-1.10** | **0.44** | **0.013** |
| **Age at wave 1** | 14 to 16 *(vs 11 to 13)* | **-0.99** | **0.18** | **<0.001** | **-1.10** | **0.48** | **0.021** | **-1.31** | **0.51** | **0.009** |
| | > 16 *(vs 11 to 13)* | **1.65** | **0.24** | **<0.001** | **1.59** | **0.68** | **0.019** | **1.61** | **0.61** | **0.008** |
| **Gender** | Female *(vs Male)* | **2.60** | **0.35** | **<0.001** | **2.23** | **0.93** | **0.016** | **2.74** | **1.01** | **0.007** |
| **First language spoken at home** | Non-English *(vs English)* | 0.06 | 0.09 | 0.49 | 0.09 | 0.16 | 0.576 | -0.07 | 0.14 | 0.609 |
| **Parental marital status** | Unmarried* *(vs Married)* | **-0.82** | **0.24** | **0.001** | **-1.21** | **0.61** | **0.048** | **-1.37** | **0.58** | **0.019** |
| **Parental education** | High school *(vs Less than high school)* | **0.43** | **0.12** | **<0.001** | **0.96** | **0.41** | **0.02** | 0.18 | 0.19 | 0.321 |
| | Some college *(vs Less than high school)* | -0.07 | 0.17 | 0.677 | 0.14 | 0.28 | 0.621 | 0.28 | 0.27 | 0.301 |
| | College *(vs Less than high school)* | 0.01 | 0.18 | 0.979 | 0.28 | 0.31 | 0.366 | 0.02 | 0.27 | 0.951 |
| **Household income** | $21,000-$38,999 *(vs $0-$20,000)* | -0.07 | 0.18 | 0.674 | 0.36 | 0.32 | 0.262 | 0.05 | 0.27 | 0.843 |
| | $39,000-$60,000 *(vs $0-$20,000)* | 0.14 | 0.13 | 0.276 | 0.38 | 0.26 | 0.152 | 0.06 | 0.21 | 0.765 |
| | Greater than $61,000 *(vs $0-$20,000)* | 0.12 | 0.14 | 0.378 | -0.02 | 0.24 | 0.949 | -0.32 | 0.24 | 0.183 |
| **Race/ethnicity** | Black/African American *(vs White)* | 0.27 | 0.16 | 0.097 | 0.61 | 0.35 | 0.087 | -0.09 | 0.24 | 0.727 |
| | Asian/Pacific Islander *(vs White)* | **-1.19** | **0.19** | **<0.001** | -0.46 | 0.27 | 0.093 | **-2.14** | **0.77** | **0.005** |
| | Other ** *(vs White)* | **-0.60** | **0.25** | **0.014** | 0.00 | 0.40 | 0.996 | **-1.54** | **0.64** | **0.017** |
| **Urbanicity of home location** | Suburban *(vs Urban)* | 0.00 | 0.17 | 0.982 | 0.88 | 0.46 | 0.057 | -0.58 | 0.35 | 0.1 |
| | Rural *(vs Urban)* | 0.20 | 0.11 | 0.066 | -0.02 | 0.18 | 0.906 | -0.01 | 0.17 | 0.942 |
| **Parental alcohol consumption** | Weekly *(vs Less than weekly)* | 0.08 | 0.11 | 0.461 | -0.25 | 0.21 | 0.231 | 0.28 | 0.20 | 0.167 |
| **Parental smoking** | Smoker *(vs Non-Smoker)* | **0.58** | **0.13** | **<0.001** | 0.19 | 0.21 | 0.365 | 0.40 | 0.24 | 0.092 |
| | | **0.59** | **0.12** | **<0.001** | **0.77** | **0.33** | **0.021** | **0.81** | **0.32** | **0.01** |
| **Weekly hobbies** | 1 or 2 times weekly *(vs None at all)* | | | | | | | | | |
| | 3 or 4 times weekly *(vs None at all)* | **-0.42** | **0.13** | **0.001** | -0.33 | 0.23 | 0.15 | **-0.66** | **0.30** | **0.026** |
| | ≥5 weekly *(vs None at all)* | **-0.76** | **0.16** | **<0.001** | **-1.00** | **0.44** | **0.022** | **-1.10** | **0.44** | **0.013** |
| **Age at wave 1** | 14 to 16 *(vs 11 to 13)* | **-0.99** | **0.18** | **<0.001** | **-1.10** | **0.48** | **0.021** | **-1.31** | **0.51** | **0.009** |
| | >16 *(vs 11 to 13)* | **1.65** | **0.24** | **<0.001** | **1.59** | **0.68** | **0.019** | **1.61** | **0.61** | **0.008** |
| **Gender** | Female *(vs Male)* | **2.60** | **0.35** | **<0.001** | **2.23** | **0.93** | **0.016** | **2.74** | **1.01** | **0.007** |

| | | Est. | SE | p | Est. | SE | p | Est. | SE | p |
|---|---|---|---|---|---|---|---|---|---|---|
| **First language spoken at home** | Non-English *(vs English)* | 0.06 | 0.09 | 0.49 | 0.09 | 0.16 | 0.576 | -0.07 | 0.14 | 0.609 |
| **Parental marital status** | Unmarried* *(vs Married)* | **-0.82** | **0.24** | **0.001** | **-1.21** | **0.61** | **0.048** | **-1.37** | **0.58** | **0.019** |
| **Parental education** | High school *(vs Less than high school)* | **0.43** | **0.12** | **<0.001** | **0.96** | **0.41** | **0.02** | 0.18 | 0.19 | 0.321 |
| | Some college *(vs Less than high school)* | -0.07 | 0.17 | 0.677 | 0.14 | 0.28 | 0.621 | 0.28 | 0.27 | 0.301 |
| | College *(vs Less than high school)* | 0.01 | 0.18 | 0.979 | 0.28 | 0.31 | 0.366 | 0.02 | 0.27 | 0.951 |
| **Household income** | $21,000-$38,999 *(vs $0-$20,000)* | -0.07 | 0.18 | 0.674 | 0.36 | 0.32 | 0.262 | 0.05 | 0.27 | 0.843 |
| | $39,000-$60,000 *(vs $0-$20,000)* | 0.14 | 0.13 | 0.276 | 0.38 | 0.26 | 0.152 | 0.06 | 0.21 | 0.765 |
| | Greater than $61,000 *(vs $0-$20,000)* | 0.12 | 0.14 | 0.378 | -0.02 | 0.24 | 0.949 | -0.32 | 0.24 | 0.183 |
| **Race/ethnicity** | Black/African American *(vs White)* | 0.27 | 0.16 | 0.097 | 0.61 | 0.35 | 0.087 | -0.09 | 0.24 | 0.727 |
| | Asian/Pacific Islander *(vs White)* | **-1.19** | **0.19** | **<0.001** | -0.46 | 0.27 | 0.093 | **-2.14** | **0.77** | **0.005** |
| | Other *(vs White)* | **-0.60** | **0.25** | **0.014** | 0.00 | 0.40 | 0.996 | **-1.54** | **0.64** | **0.017** |
| **Urbanicity of home location** | Suburban *(vs Urban)* | 0.00 | 0.17 | 0.982 | 0.88 | 0.46 | 0.057 | -0.58 | 0.35 | 0.1 |
| | Rural *(vs Urban)* | 0.20 | 0.11 | 0.066 | -0.02 | 0.18 | 0.906 | -0.01 | 0.17 | 0.942 |
| **Parental alcohol consumption** | Weekly *(vs Less than weekly)* | 0.08 | 0.11 | 0.461 | -0.25 | 0.21 | 0.231 | 0.28 | 0.20 | 0.167 |
| **Parental smoking** | Smoker *(vs Non-Smoker)* | **0.58** | **0.13** | **<0.001** | 0.19 | 0.21 | 0.365 | 0.40 | 0.24 | 0.092 |

*Note: 'Unmarried' marital status category includes: divorced, separated, widowed, and never married.*
*'Other' race/ethnicity category includes: Hispanic and American Indian/Native American.*

**Table S3. Sensitivity Analysis full Model. Associations of the arts and cultural group participation and weekly hobbies predictors on the intercept and slopes from the conditional latent growth models**

| | | Weekly alcohol intoxication | | | | | |
|---|---|---|---|---|---|---|---|
| | | *b* | *SE* | *p* | *b* | *SE* | *p* |
| | | **Predictors of the intercept** | | | **Predictors of the slope** | | |
| **Arts and cultural group participation** | 1 Activity *(vs 0 activities)* | -0.51 | 0.27 | 0.057 | 0.19 | 0.16 | 0.215 |
| | ≥ 2 Activities *(vs 0 activities)* | **-1.58** | **0.55** | **0.004** | **0.79** | **0.31** | **0.011** |
| **Age at wave 1** | 14 to 16 *(vs 11 to 13)* | **1.50** | **0.37** | **<0.001** | **-0.81** | **0.21** | **<0.001** |
| | > 16 *(vs 11 to 13)* | **3.00** | **0.40** | **<0.001** | **-1.78** | **0.23** | **<0.001** |
| **Gender** | Female *(vs Male)* | -0.37 | 0.20 | 0.063 | **-0.46** | **0.12** | **<0.001** |
| **First language spoken at home** | Non-English *(vs English)* | **-1.18** | **0.47** | **0.013** | 0.32 | 0.28 | 0.261 |
| **Parental marital status** | Unmarried* *(vs Married)* | 0.25 | 0.23 | 0.268 | -0.04 | 0.13 | 0.774 |
| **Parental education** | High school *(vs Less than high school)* | 0.24 | 0.33 | 0.472 | 0.04 | 0.21 | 0.846 |
| | Some college *(vs Less than high school)* | 0.03 | 0.36 | 0.927 | 0.19 | 0.23 | 0.403 |
| | College *(vs Less than high school)* | -0.17 | 0.38 | 0.658 | 0.45 | 0.23 | 0.056 |
| **Household income** | $21,000-$38,999 *(vs $0-$20,000)* | -0.29 | 0.28 | 0.301 | 0.21 | 0.17 | 0.204 |
| | $39,000-$60,000 *(vs $0-$20,000)* | -0.46 | 0.30 | 0.121 | **0.37** | **0.17** | **0.034** |
| | Greater than $61,000 *(vs $0-$20,000)* | **-0.96** | **0.37** | **0.010** | **0.84** | **0.22** | **<0.001** |
| **Race/ethnicity** | Black/African American *(vs White)* | -0.25 | 0.29 | 0.393 | -0.30 | 0.17 | 0.075 |
| | Asian/Pacific Islander *(vs White)* | -0.41 | 0.49 | 0.398 | -0.55 | 0.30 | 0.067 |
| | Other ** *(vs White)* | **0.65** | **0.33** | **0.049** | -0.27 | 0.19 | 0.155 |
| **Urbanicity of home location** | Suburban *(vs Urban)* | 0.03 | 0.24 | 0.905 | 0.01 | 0.14 | 0.972 |
| | Rural *(vs Urban)* | 0.12 | 0.26 | 0.645 | -0.07 | 0.15 | 0.656 |
| **Parental alcohol consumption** | Weekly *(vs Less than weekly)* | 0.46 | 0.27 | 0.090 | -0.03 | 0.15 | 0.849 |
| **Parental smoking** | Smoker *(vs Non-Smoker)* | **0.69** | **0.22** | **0.002** | **-0.33** | **0.13** | **0.011** |
| **Weekly hobbies** | 1 or 2 times weekly *(vs None at all)* | **-0.85** | **0.26** | **0.001** | 0.23 | 0.15 | 0.122 |
| | 3 or 4 times weekly *(vs None at all)* | **-1.29** | **0.31** | **<0.001** | **0.45** | **0.17** | **0.009** |
| | ≥5 weekly *(vs None at all)* | **-1.24** | **0.30** | **<0.001** | **0.52** | **0.17** | **0.003** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Age at wave 1** | 14 to 16 *(vs 11 to 13)* | **1.52** | **0.38** | **<0.001** | **-0.82** | **0.21** | **<0.001** |
| | >16 *(vs 11 to 13)* | **3.02** | **0.41** | **<0.001** | **-1.79** | **0.23** | **<0.001** |
| **Gender** | Female *(vs Male)* | **-0.60** | **0.20** | **0.002** | **-0.35** | **0.12** | **0.002** |
| **First language spoken at home** | Non-English *(vs English)* | **-1.14** | **0.47** | **0.015** | 0.31 | 0.28 | 0.278 |
| **Parental marital status** | Unmarried* *(vs Married)* | 0.24 | 0.23 | 0.298 | -0.03 | 0.13 | 0.844 |
| **Parental education** | High school *(vs Less than high school)* | 0.21 | 0.34 | 0.540 | 0.06 | 0.21 | 0.791 |
| | Some college *(vs Less than high school)* | 0.03 | 0.37 | 0.939 | 0.20 | 0.23 | 0.393 |
| | College *(vs Less than high school)* | -0.18 | 0.39 | 0.643 | 0.45 | 0.24 | 0.056 |
| **Household income** | $21,000-$38,999 *(vs $0-$20,000)* | -0.27 | 0.28 | 0.333 | 0.21 | 0.17 | 0.200 |
| | $39,000-$60,000 *(vs $0-$20,000)* | -0.40 | 0.30 | 0.190 | **0.35** | **0.18** | **0.047** |
| | Greater than $61,000 *(vs $0-$20,000)* | **-0.89** | **0.37** | **0.018** | **0.81** | **0.22** | **<0.001** |
| **Race/ethnicity** | Black/African American *(vs White)* | -0.27 | 0.29 | 0.352 | -0.29 | 0.17 | 0.094 |
| | Asian/Pacific Islander *(vs White)* | -0.39 | 0.50 | 0.430 | -0.54 | 0.30 | 0.071 |
| | Other *(vs White)* | **0.65** | **0.33** | **0.052** | -0.26 | 0.19 | 0.165 |
| **Urbanicity of home location** | Suburban *(vs Urban)* | 0.05 | 0.25 | 0.848 | 0.00 | 0.14 | 1.000 |
| | Rural *(vs Urban)* | 0.10 | 0.26 | 0.692 | -0.06 | 0.15 | 0.695 |
| **Parental alcohol consumption** | Weekly *(vs Less than weekly)* | 0.48 | 0.27 | 0.075 | -0.04 | 0.15 | 0.797 |
| **Parental smoking** | Smoker *(vs Non-Smoker)* | **0.72** | **0.23** | **0.001** | **-0.35** | **0.13** | **0.008** |

Note: 'Unmarried' marital status category includes: divorced, separated, widowed, and never married.
'Other' race/ethnicity category includes: Hispanic and American Indian/Native American.