Full length article

Childhood language development and later alcohol use behaviors

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ABSTRACT

Background: Studies have shown a correlation between language abilities and alcohol use; however, results are inconsistent. A recent study using a discordant twin design showed an association between early child language development and later alcohol use behaviors; i.e., the twin with more advanced language abilities was more likely to try alcohol earlier in adolescence (Latvala et al., 2014). The authors suggested that this could result from better socialization of individuals with greater language abilities, which could lead to more opportunities for alcohol experimentation. The findings by Latvala et al. raise interesting questions, but the study has limitations, and replication is needed.
Method: We aimed to replicate and build upon these results utilizing 488 same sex twin pairs from the Colorado Longitudinal Twin Study, a longitudinal sample with quantitative measures of language abilities starting when the twins were 14 months old.
Results: We found no significant correlations between a latent measure of child language abilities or measures of general cognitive ability at ages 14, 20, and 24 months and a latent alcohol use variable at ages 17 and 22 years.
Conclusion: Our results did not replicate the association between early language ability and later alcohol use reported by Latvala et al. Possible reasons for differing results across samples, including varying cultural norms as well as differences in educational attainment, peer influences, and novelty seeking, were discussed.

1. Introduction

Studies have shown a correlation between language abilities and alcohol use; however, results are inconsistent (see Table 1). Some studies report that individuals with greater cognitive and language abilities use alcohol earlier in adolescence and more frequently in adulthood (e.g., Latvala et al., 2014; Wilmoth, 2012; Kanazawa and Hellberg, 2010), whereas other studies report that those with poorer cognitive abilities have an increased risk of binge drinking and alcohol-related mortality (e.g., Jefferis et al., 2008; Sjolund et al., 2012). As such, studies have shown differing pathways between cognitive abilities and the onset of substance experimentation versus the onset of more problematic substance use behaviors (e.g., Pagan et al., 2006; Rhee et al., 2003; Young et al., 2006). However, early substance experimentation is a strong predictor of later problematic substance use (e.g., Fergusson et al., 2008). Because early alcohol experimentation is associated with problem use, one might expect the correlation between cognitive abilities and alcohol experimentation to be in the same direction as the correlation between cognitive abilities and alcohol problem use. Thus, the relationship between cognitive abilities and normative versus problematic alcohol use behaviors is unclear, and varying explanatory hypotheses have been suggested.

Specifically, researchers who have found a positive correlation between cognitive abilities and earlier alcohol experimentation have invoked the Savanna-IQ Interaction Hypothesis to suggest that individuals with higher cognitive abilities may be more novelty seeking than individuals with lower cognitive abilities (e.g., Kanazawa and Hellberg, 2010), and increased novelty seeking may increase the likelihood of experimenting with alcohol at an earlier age (e.g., Wilmoth, 2012; Kanazawa and Hellberg, 2010; Raine et al., 2002). Further, cognitive abilities are often correlated with language abilities, and superior language abilities may improve the relative social standing during childhood/adolescence, increasing probability of exposure to alcohol (Latvala et al., 2014; Menting et al., 2011). In contrast, studies finding a negative correlation between cognitive abilities and alcohol use hypothesize that cognitive abilities can be protective against

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Table 1
Review of recent literature on the correlation between language and cognitive abilities and alcohol use behaviors.

Article	Predictive Measure	Outcome Measure	r
Latvala et al. (2014)	Language Development at 7-12 yrs.	Frequency of drinking, intoxication, and alcohol-related problems at 12-22 yrs. or 16-25 yrs.	positive
Sjolund et al. (2012)	Intelligence at 18-19 yrs.	Alcohol related hospitalization and mortality before 55-56 yrs.	negative
Wilmoth, (2012)	Intelligence at 15-23 yrs.	Alcohol experimentation at 17-37 yrs.	positive
Kanazawa and Hellberg, (2010)	Intelligence at 7, 11, and 16 yrs.	Frequency of drinking alone and quantity at 23, 33, and 42 yrs.	positive
Kanazawa and Hellberg, (2010)	Vocabulary and Intelligence at 15 yrs.	Frequency, quantity, and heavy use at 22 yrs.	positive
Johnson et al. (2010)	Intelligence at 17 yrs.	Alcohol abuse/dependence, number of intoxications, frequency, and quantity at 17 and 24 yrs.	mixed
Batty et al. (2008)	Intelligence at 10 yrs.	Alcohol-related problems and risk of problems at 30 yrs.	positive
Jefferis et al. (2008)	Intelligence at 7, 11, and 16 yrs.	Frequency and quantity at 22, 33, and 42 yrs.	mixed
Hatch et al. (2007)	Intelligence at 8 yrs.	Potential alcohol abuse at 53 yrs.	positive

Note. yrs. = years. Mixed indicates that results were not consistently positive or negative.

problem alcohol use (e.g., Sjolund et al., 2012). The authors of this study hypothesize that improved cognitive abilities may correlate with better comprehension and integration of health-related information, and lower likelihood to engage in problematic alcohol use behaviors (Sjolund et al., 2012). Again, this hypothesis indicates verbal comprehension as an explanation for possible correlations between cognitive abilities and alcohol use.

In studies investigating the correlation between alcohol use and both cognitive and language abilities, the correlation is generally examined longitudinally between early cognitive/language functioning and later alcohol use. It is important to note that these early cognitive and language measures have been correlated with intellectual functioning, language abilities, and educational attainment into adolescence and adulthood (e.g., Hohm et al., 2007; Murray et al., 2007). Early cognitive and language functioning may be correlated with later alcohol use either due to stability in these traits or possibly due to the impacts on early socialization, which may also be stable into adolescence. Despite the literature on early cognitive abilities as a predictor of later alcohol use behaviors and language abilities as a hypothesized mechanism, few studies have investigated the specific influence of language abilities on later alcohol experimentation.

A recent study by Latvala et al. (2014) used a discordant twin-pair analysis to address this gap in the literature, including monozygotic (MZ), dizygotic (DZ), and opposite-sex (OS) twin pairs. The authors evaluated a Finnish sample of twins differing in early language development, per parent retrospective report, and in age of alcohol use initiation, expecting that the earlier-speaking twins would experiment with alcohol earlier and more frequently than their later-speaking co-twins. The authors used a discordant twin-pair design, which addresses possible confounding variables, including genetic-relatedness, sex, age, birth-cohort, and family confounding variables, such as socioeconomic status and parent substance use. Their sample included a cohort (F16) born between 1975–1979 and a cohort (F12) born between 1983–1987; the authors noted possible cohort effects due to an economic depression when the F16 twins were adolescents and an economic boom when the F12 twins were adolescents. Their results broadly suggested that the earlier-speaking twin tended to report more frequent drinking behaviors in adolescence than their later-speaking co-twin, and the earlier-reading twin tended to report more frequent drinking in young adulthood than their later-reading co-twin. However, patterns of significance varied between F12 and F16 samples, with no specific odds ratios achieving significance in both samples. In the F16 sample, twins with more advanced early expressive language abilities were less likely to abstain from alcohol at age 16 years, more likely to drink frequently in young adulthood, and more likely to report intoxication in adolescence and young adulthood. In contrast, there were no significant correlations in the F12 sample between expressive language abilities and alcohol use. Still, in the F12 sample, twins who spoke earlier were more likely to drink frequently at age 14 years and to drink more at age 22 years. Additional exploratory analyses suggested that the twin with earlier

verbal development was more likely to have friends who use alcohol and to be somewhat more sensation-seeking.

While these findings are consistent with the hypothesis that individuals with better language abilities will be exposed to more social situations with more opportunities to use alcohol, the authors noted some limitations in their study: none of the results were replicated between cohorts, suggesting likely cohort effects in the sample; verbal development was measured by retrospective parent report of which twin was earlier speaking, which may introduce rater bias; and because there was no direct assessment of verbal ability, the study was unable to examine the magnitude of co-twin differences in verbal ability.

The present study aims to replicate these findings by examining the correlation between early language abilities and later alcohol use behaviors in a large, longitudinal twin sample. We utilized a sample with latent factors of direct measures of language ability in childhood to address the limitations noted by Latvala et al. (2014). We predicted that individuals with better language abilities in early development will experiment with alcohol at an earlier age than individuals with poorer language abilities. We also conducted exploratory analyses, investigating discordant MZ twin pair analyses similar to those conducted by Latvala et al. (2014). Additionally, we tested the association between general cognitive abilities with later alcohol use behaviors.

2. Method

2.1. Participants

Participants were 488 same-sex twin pairs (264 MZ, 221 DZ, 3 unknown zygosities) born between 1986 and 1990 who participated in the Longitudinal Twin Study and the Center on Antisocial Drug Dependence (Rhea et al., 2013). Data for this study were collected when the twins were ages 14–36 months (early language and cognitive abilities) and at 17 and 22 years (alcohol use).

2.2. Measures

Expressive and receptive language abilities were measured at 14, 20, 24, and 36 months using the Sequenced Inventory of Communication Development (SICD; Hedrick et al., 1975) that assesses both expressive and receptive language. While language abilities were assessed longitudinally throughout the twin's development, very early measures of language abilities were used to best replicate the study by Latvala et al. (2014). Items were selected for inclusion in the study based on age-appropriateness of the question (e.g., Hedrick et al., 1975); thus, different items were used at the 36-month time point compared with the 14-, 20-, and 24-month time points. To measure expressive language abilities, children were asked questions designed to elicit particular sounds or words (e.g., "What says 'meow?'"), whereas receptive language abilities were measured by giving commands that determine a child's understanding of words and phrases (e.g., "Give me

Table 2
Descriptive statistics of continuous predictor and outcome variables.

Measure/Age	Mean	Standard Deviation
Receptive and Expressive Language[a]		
Age 14 months	19.05	4.22
Age 20 months	32.48	5.59
Age 24 months	41.05	5.36
Age 36 months[b]	10.07	4.26
Cognitive Abilities[c]		
Age 14 months	112.43	5.50
Age 20 months	136.06	8.54
Age 24 months	148.78	8.29
Age 36 months[d]	103.13	17.70
Alcohol Use Variables		
Age of onset	15.90 years	3.11
Average weekly quantity at 17 years[e]	5.17 drinks	8.65
Average weekly quantity at 22 years[e]	7.99 drinks	13.11

[a] SICD-R estimates include a combination of expressive and receptive language abilities.

[b] Due to differences in age-appropriateness of the measure, different test items were used for the age 36 month wave.

[c] The Bayley was used at ages 14–24 months. Population mean = 100, standard deviation = 15.

[d] The Stanford-Binet was used at age 36 months. Population mean = 100, standard deviation = 15.

[e] Log-transformed quantity is used in analyses. Descriptive statistics from raw data are shown here.

the shoe and the dog."). Expressive and receptive abilities were evaluated together as a total language score. A latent factor of language abilities with loadings on the total language score at each time point was used in all analyses. Descriptive statistics for the SICD at each age are displayed in Table 2.

Cognitive abilities were assessed using the Mental Development Index (MDI) of the Bayley Scales of Mental Development (Bayley, 1969) at ages 14, 20, and 24 months. The Bayley Scales of Mental Development includes 90 items that evaluate fine-motor skills, problem solving abilities, and vocabulary. The Stanford-Binet Form L-M intelligence quotient score (Terman and Merrill, 1973), which is a measure of overall cognitive abilities, was used at age 36 months. A latent factor with loadings on the cognitive measure at each time point was used throughout the study. Descriptive statistics for the Bayley and Stanford-Binet scores at all time points are displayed in Table 2.

Adolescent substance use was assessed using the Composite International Diagnostic Interview Substance Abuse Module and Supplement (CIDI-SAM; Cottler et al., 1989) at ages 12, 17, and 22 years. Preliminary analyses showed that very few individuals endorsed alcohol use at age 12, so these data were excluded from analyses. Alcohol use indicators were selected based on availability in the present sample and similarity to measures examined by Latvala et al. (2014), which included measures of frequency, problem use, maximum quantity, and alcohol use or abstinence across ages. As such, measures of alcohol use include frequency of alcohol use each month ("frequency"), number of drinks in the average week ("amount"), number of DSM-IV (APA, 2000) criteria met for alcohol abuse and dependence ("problem use"), and age when first tried alcohol ("age of onset"). Age of onset was asked of participants at all three time points. To reduce retrospective reporting bias, age of onset was taken from the earliest time point at which each participant endorsed experimenting with alcohol (age 12 - n = 39, age 17 - n = 409, age 22 - n = 737). Descriptive statistics for the amount and onset variables are displayed in Table 2, and descriptive statistics for the frequency and problem use categorical variables are displayed in Table 3. Each of these variables was correlated with all other variables at both time points to determine the appropriateness of a latent factor of alcohol use. There were significant correlations between different measures of alcohol use within and across age at the $p < .05$ or $p < .01$ level (see Supplemental Table A).

Table 3
Descriptive statistics of ordinal outcome variables.

Measure/Age	Outcomes	Frequency[*]
Number of DSM-IV Problem Use Symptoms		
Age 17 years	None	604
	1 symptom	75
	2 or more symptoms	114
Age 22 years	None	327
	1 symptom	138
	2 or more symptoms	297
Frequency of Alcohol Use		
Age 17 years	Less than once monthly	232
	Less than once weekly	114
	Once weekly or more often	63
Age 22 years	Less than once monthly	117
	Less than once weekly	196
	Once weekly or more often	424

[*] Number of participants endorsing this response category.

2.3. Data analysis

Data were analyzed using Mplus 7 (Muthén and Muthén, 1998–2014Muthén and Muthén, 1998Muthén and Muthén, 1998–2014) using weighted least squares mean and variance adjusted (WLSMV) estimation, which assumes categorical data come from an underlying continuous distribution. WLSMV uses pairwise deletion for missing data (Little and Rubin, 2002). Type = COMPLEX was used to address the nested structure of the twins within families in the calculation of standard errors and model fit. Latent factors of alcohol use and language abilities were estimated using confirmatory factor analysis. Chi-squared tests, comparative fit indices (CFI; Bentler, 1990), and root-mean-square error of approximation (RMSEA; Browne and Cudeck, 1987; Steiger and Lind, 1980) were used as estimates of model fit. Good model fit is indicated by CFI greater than .95 and RMSEA less than .06 (Hu and Bentler, 1998). All final models met these requirements for good model fit (see Supplemental Figure A and Fig. 1).

3. Results

We examined the appropriateness of a higher order alcohol use factor to conduct a single analysis correlating language abilities and alcohol use (see Supplemental Figure A)[2]. Frequency, amount, and problem use at age 17 years loaded onto a 17-year factor, and frequency, amount, problem use, and age of alcohol experimentation reported at age 22 loaded onto a 22-year factor. In order for the measurement model to be identified, the higher order alcohol use factor's loadings on the 17-year and 22-year factors were equated, although variance was free. Residual correlations were allowed between problem use at age 17 and problem use at age 22 and between problem use at age 17 and age of onset reported at age 22 to improve model fit, given the stability of problem use across age and expected negative correlation between age of initiation and problem use (e.g., Fergusson et al., 2008). Loadings and residual correlations were all significant at the $p < .05$ level. The latent factor model fit the data well, χ^2 (11) = 17.37, $p = .10$, RMSEA = .03, CFI = .99, and is used in later analyses as the measure of alcohol use. A higher order language ability factor was estimated with loadings on SICD expressive and receptive language abilities estimated at ages 14 months, 20 months, 24 months, and 36 months. With the addition of a residual correlation between abilities at 24 and 36 months, which were highly correlated, the latent factor model of language abilities fit the data well, χ^2 (1) = .62, $p = .43$, RMSEA = .00, CFI = 1.00.

A model correlating a latent factor of early language abilities with a higher-order factor of alcohol use, shown in Fig. 1, fit the data well, χ^2 (40) = 61.94, $p = .01$, RMSEA = .02, CFI = .98. The correlation between early language and later alcohol use was nominally, but not
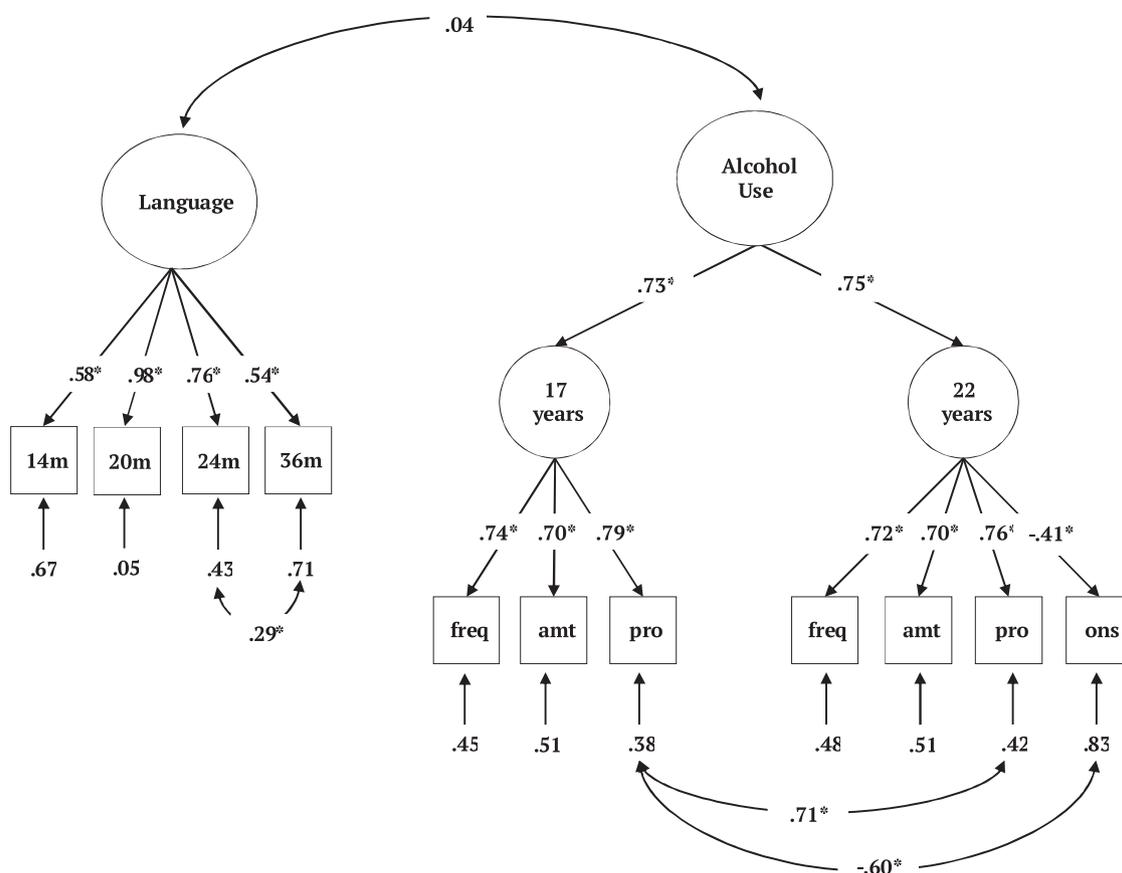
Fig. 1. Correlation between latent factor of language abilities and a higher-order factor of alcohol use. Factor loadings are shown above indicator variables, and residual variances are shown below indicator variables. Lang = language latent factor; freq = frequency of alcohol use over the past month; amt = amount of alcohol consumed over the past week; pro = number of DSM-IV symptoms of alcohol abuse or dependence; ons = age of onset of alcohol use as reported by age 22 years. Model fit: χ^2 (39) = 57.86, RMSEA = .02, CFI = .98. *p < .05.

significantly higher than zero (r = .04, p = .59). Follow up analyses examined correlations between early language abilities and each individual alcohol use variable as well as with the higher-order latent factor of alcohol use variables (see Supplemental Table B), but none of the 8 correlations (range r = .02 to r = .24) was statistically significant. Language abilities and frequency of alcohol use at age 22 years were marginally correlated (r = .11, p = .05). However, due to the number of correlations tested, this is likely to be a spurious finding. Additionally, the proportion of variance explained by this association was extremely small (less than 2%).

Correlations were evaluated between cognitive abilities and individual alcohol use variables and the higher-order factor of alcohol use variables (see Supplemental Table C), and overall cognitive abilities and alcohol use were not significantly correlated (r = -.04, p = .61). Cognitive abilities and frequency of alcohol use at age 22 years were nominally correlated (r = .14, p = .02); however, no other alcohol use variables were significantly correlated with early cognitive abilities. This correlation would not be significant after controlling for false positives due to multiple testing.

Exploratory analyses were conducted using the discordant monozygotic twin pairs design, thus more directly replicating the discordant analysis completed by Latvala et al. (2014). The analysis calculated the difference score within twin pairs for each alcohol use variable and the language composite variable using a latent difference score approach. The results are consistent with the aforementioned results, with no evidence for significant correlations between language abilities and alcohol use. Specifically, in our sample, the twin with more advanced early language abilities was not significantly more likely to engage in

any alcohol use behaviors in adolescence (range r = .029 to r = .068, all ps > .10).

Had the correlations between alcohol use and early language and cognitive abilities been significant, follow up genetic analyses would have been performed to investigate the relative magnitude of genetic, shared environmental, and nonshared environmental covariance on the association, which would allow investigation of a possible causal influence between language and cognitive abilities and alcohol use. However, due to null phenotypic associations, these analyses were not run.

4. Discussion

The present study aimed to replicate findings of a study by Latvala et al. (2014), by using a large sample and improved measures of language ability, alcohol use, and cognitive abilities to test the hypothesis that earlier language abilities are associated with later alcohol use. Latvala et al. found a positive correlation between early language abilities and later alcohol use. We did not replicate the results of Latvala et al. in this study, finding no significant association between language development and alcohol use behaviors. Discordant twin designs yielded consistent results and consequently did not support a causal pathway between early language ability and later alcohol use. Follow up analyses showed that there was no significant correlation between specific alcohol variables and early language abilities. Cognitive abilities and alcohol use were also not significantly correlated. For both early language abilities and cognitive abilities, the correlation with frequency of alcohol use at age 22 years was positive, but this result is

likely spurious given the multiple tests performed.

Our results may differ from those of Latvala et al. (2014) due to existing cultural differences surrounding alcohol use between the United States and Finland. However, there is also the possibility that there are multiple mechanisms between language abilities and alcohol use, which may lead to positive associations in some individuals and negative associations in others. For instance, better language ability could lead to more opportunities for socializing, which could result in earlier alcohol experimentation and more frequent alcohol use. In contrast, worse language ability could lead to school difficulties and more externalizing behaviors, which could also result in more alcohol experimentation and more frequent alcohol use. It is possible that there is a different direction of effect depending on the background environment of the individual (e.g., Dodge et al., 2009; Menting et al., 2011; Latvala et al., 2014), which could cancel out true effects and lead to null findings, as in the present study. Future studies may also investigate language abilities into adolescence, at a time point more proximate to alcohol experimentation, to evaluate the association between adolescent language abilities, socialization, and alcohol experimentation.

The present study has many strengths, specifically addressing several of the limitations mentioned by Latvala et al. (2014) by using direct and quantitative measures of early language and cognitive abilities. Our study also includes a large, prospective, longitudinal sample, which addresses possible rater bias and cohort effects in the study by Latvala et al. (2014). However, our study also has limitations. Retrospective reporting of age of onset is a limitation of the study, as these data may not be as accurate as more proximal measures of onset of alcohol use. Additionally, because we aimed to closely replicate the study by Latvala et al. (2014), we did not investigate potential mediators of the correlations between language abilities and alcohol use, including adolescent verbal abilities and social functioning. As such, additional large studies that analyze possible mechanisms underlying the association between language abilities and alcohol use are needed to improve understanding of the mixed results in the literature. Specifically, it will be important to incorporate predictors such as education, peer influences, and novelty seeking that might be important mediators of any relationship between language development, cognitive abilities, and alcohol use (e.g., Dodge et al., 2009; Wilmoth, 2012; Kanazawa and Hellberg, 2010; Latvala et al., 2014).

Contributors

All authors have contributed to and approved the final manuscript. Woodward, Friedman, Hatoum, Huibregtse, and Rhee contributed to the design and data analyses of the study. Corley, Friedman, Hewitt, Stallings, and Rhee contributed to the data collection. All authors contributed significantly to the writing and review of the manuscript.

Conflict of interest

No conflict declared.

Informed consent

Informed consent was obtained from all individual participants included in the study.

References

American Psychiatric Association, 2000. Diagnostic and Statistical Manual of Mental Disorders: DSM-IV-TR. American Psychiatric Association, Washington, DC.

Batty, G.D., Dreary, I.J., Schoon, I., Emslie, C., Hunt, K., Gale, C.R., 2008. Childhood mental ability and adult alcohol intake and alcohol problems: the 1970 British cohort study. Am. J. Public Health 98, 2237–2243.

Bayley, N., 1969. Manual for the Bayley Scales of Infant Development. The Psychological Corporation, San Antonio, TX.

Bentler, P.M., 1990. Comparative fit indexes in structural models. Psych. Bull. 107, 238–246. https://doi.org/10.1037/0033-2909.107.2.238.

Browne, M.W., Cudeck, R., 1987. Alternative ways of assessing model fit. In: Bollen, K.A., Long, J.S. (Eds.), Testing Structural Equation Model. Sage Publications, Inc., Newbury Park, CA, pp. 136–162.

Cottler, L.B., Robins, L.N., Helzer, J.E., 1989. The reliability of the CIDI-SAM: a comprehensive substance abuse interview. Br. J. Addict. 84, 801–814.

Dodge, K.A., Malone, P.S., Lansford, J.E., Miller, S., Pettit, G.S., Bates, J.E., 2009. A dynamic cascade model of the development of substance-use onset. Monogr. Soc. Res. Child Dev. 74, 1–31.

Fergusson, D.M., Boden, J.M., Horwood, L.J., 2008. The developmental antecedents of illicit drug use: evidence from a 25-year longitudinal study. Drug Alcohol Depend. 96, 165–177.

Hatch, S., Jones, P., Kuh, D., Hardy, R., Wadsworth, M.E.J., Richards, M., 2007. Childhood cognitive ability and adult mental health in the British 1946 birth cohort. Soc. Sci. Med. 64, 2285–2296.

Hedrick, D.L., Prather, E.M., Tobin, A.R., 1975. Sequenced Inventory of Communication Development. University of Washington Press, Seattle, WA.

Hohm, E., Jennen-Steinmetz, C., Schmidt, M.H., Laucht, M., 2007. Language development at ten months: Predictive of language outcome and school achievement ten years later? Eur. Child Adolesc. Psychiatry 16, 149–156. https://doi.org/10.1007/s00787-006-0567-y.

Hu, L.T., Bentler, P.M., 1998. Fit indices in covariance structure modeling: sensitivity to underparameterized model misspecification. Psychol. Methods 3, 424–453. https://doi.org/10.1037/1082-989X.3.4.424.

Jefferis, B.J.M.H., Manor, O., Power, C., 2008. Cognitive development in childhood and drinking behaviour over two decades in adulthood. J. Epidemiol. Commun. Health 62, 506–512.

Johnson, W., Hicks, B.M., McGue, M., Iacono, W.G., 2010. Hints from the Minnesota twin family study. Intelligence 37, 613–624.

Kanazawa, S., Hellberg, J.E.E.U., 2010. Intelligence and substance use. Rev. Gen. Psychol. 14, 382–396.

Latvala, A., Rose, R.J., Pulkkinen, L., Dick, D.M., Kaprio, J., 2014. Childhood verbal development and drinking behaviors from adolescence to young adulthood: a discordant twin-pair analysis. Alcohol. Clin. Exp. Res. 38, 457–465.

Little, R.J.A., Rubin, D.B., 2002. Statistical Analysis with Missing Data, second ed. John Wiley and Sons, New York.

Menting, B., Van Lier, P., Koot, H., 2011. Language skills, peer rejection, and the development of externalizing behavior from kindergarten to fourth grade. J. Child Psychol. Psychiatry 52, 72–79.

Murray, G.K., Jones, P.B., Kuh, D., Richards, M., 2007. Infant developmental milestones and subsequent cognitive function. Ann. Neurol. 62, 128–136. https://doi.org/10.1002/ana.21120.

Muthén, L.K., Muthén, B.O., 2014. Mplus User's Guide, seventh ed. Muthén and Muthén, Los Angeles, CA.

Pagan, J.L., Rose, R.J., Viken, R.J., Pulkkinen, L., Kaprio, J., Dick, D.M., 2006. Genetic and environmental influences on stages of alcohol use across adolescence and into young adulthood. Behav. Genet. 36, 483–497.

Raine, A., Reynolds, C., Venables, P.H., Mednick, S.A., 2002. Stimulation seeking and intelligence: a prospective longitudinal study. J. Pers. Soc. Psychol. 82, 663–674.

Rhea, S.-A., Gross, A.A., Haberstick, B.C., Corley, R.P., 2013. Colorado Twin Registry - an update. Twin Res. Hum. Genet. 16, 1–14. https://doi.org/10.1017/thg.2012.93.

Rhee, S.H., Hewitt, J.K., Young, S.E., Corley, R.P., Crowley, T.J., Stallings, M.C., 2003. Genetic and environmental influences of substance initiation, use, and problem use in adolescents. Arch. Gen. Psychiatry 60, 1256–1264.

Sjolund, S., Alleback, P., Hemmingsson, T., 2012. Intelligence quotient (IQ) in adolescence and later risk of alcohol-related hospital admissions and deaths – 37-year follow-up of Swedish conscripts. Addiction 107, 89–97.

Steiger, J.H., Lind, J.C., 1980. Statistically based tests for the number of common factors. Annual Meeting of the Psychometric Society 178.

Terman, L.M., Merrill, M.A., 1973. Stanford-Binet Intelligence Scale: Manual for the Third Revision Form L-M (1972 Norm Tables by R.L. Thorndike). Houghton Mifflin, Boston, MA.

Wilmoth, D.R., 2012. Intelligence and past use of recreational drugs. Intelligence 40, 15–22.

Young, S.E., Rhee, S.H., Stallings, M.C., Corley, R.P., Hewitt, J.K., 2006. Genetic and environmental vulnerabilities underlying adolescent substance use and problem use: general or specific? Behav. Genet. 36, 603–615. https://doi.org/10.1007/s10519-006-9066-7.